TD
426
.L68
1989
MOE

STANDARDS DEVELOPMENT BRANCH OMOE
36936000004945

ENVIRONMENTAL RESEARCH

RESEARCH AND TECHNOLOGY BRANCH

Environment
Ontario
Jim Bradley, Minister

[redacted]

TD
426
.L68
1989

Low cost treatment technology
for gasoline contaminated
groundwater-delta, Ontario /
Woeller, R. M.

77116

ISBN: 0-7729-5833-5

LOW COST TREATMENT TECHNOLOGY FOR GASOLINE CONTAMINATED GROUNDWATER-DELTA, ONTARIO

R. A. C. PROJECT NO. 291-PL

Report prepared for Environment Ontario by:

R.M. Woeller, J.F. Devlin and T.R. Keil
Water and Earth Science Associates Ltd.
Box 430, Carp, Ontario
K0A 1L0
JUNE 1988

JULY 1989

RECYCLABLE

Copyright: Queen's Printer for Ontario, 1989

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

DISCLAIMER

"This report has been reviewed by the Research Advisory Committee of the Ministry of the Environment and approved for publication. Approval does not necessarily signify that the contents reflect the views and/or policies of the Ontario Ministry of the Environment nor does mention of trade names or commercial products constitute endorsement or recommendation for use".

ACKNOWLEDGEMENTS

This report is issued to describe an environmentally orientated research project conducted by Water and Earth Science Associates Ltd., at Delta, Ontario and supplemented by a contract with the Research Management Office, Policy and Planning Branch, of the Ontario Ministry of the Environment. All enquiries regarding this project should be directed to Mr. D.J. Cook, P.Eng. (Southeastern Region) or to the Research Management Office of the Ontario Ministry of the Environment.

Water and Earth Science Associates would like to thank Mr. J. Ingram of A.E. Williams & Company Ltd. for permission to publish field data from the Delta Project.

Generous field help was given by Mr. D.J. Cook and his associates at the Southeastern Region office of the Ministry of the Environment. Water and Earth Science Associates Ltd., appreciates the invaluable assistance by the staff and facilities of the Mobile Trace Organic Laboratory of the Laboratory Service Branch.

Ms. C. Ulmann did the drafting of the figures.

Thanks are extended to all the residents of the hamlet of Delta who provided information and water samples to the field crews, thus ensuring the successful completion of the survey work.

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 BACKGROUND INFORMATION 2

3.0 SITE DESCRIPTION 2
  3.1 Geology 2
  3.2 Drainage 3

4.0 TREATMENT FIELD DESIGN 3

5.0 TREATMENT FACILITY RESULTS 5
  5.1 Operational Phase 5
    5.1.1 Water Flow: A Field 5
    5.1.2 Water Flow: B Field 6
    5.1.3 System Water Flow 6
    5.1.4 V-Notch Weir Water Flow 6
  5.2 Water Quality Sampling 7
  5.3 Homeowner Water Quality 8
  5.4 Hydraulic Response of the Aquifer 9
    5.4.1 Drawdown in the Pumping Well 9
  5.5 Air Quality Monitoring 10

6.0 WESA-MOE DETAILED CHEMICAL ANALYSIS 10
  6.1 Water Chemistry Monitoring Program 1
  6.2 Sampling Methods 11
  6.3 Flow Cell Measurements 12
  6.4 WESA-MOE Results and Discussion 12
    6.4.1 Private Wells 12
    6.4.2 Overburden / Bedrock Piezometers 13
    6.4.3 Treatment Field 13
    6.4.4 Inorganic Chemistry 14
    6.4.5 Organic Chemistry 15

7.0 CONCLUSIONS 16

8.0 REFERENCES 18

LIST OF APPENDICES

Appendix A Ministry of Environment Certificate of Approval
Appendix B Water Treatment Chemistry Analysis
Appendix C Benzene in Home Wells
Appendix D Piezometer Water Levels

LIST OF FIGURES

Figure 1 Location Map
Figure 2 Site Plan
Figure 3 Cumulative Water Flow, System Totals
Figure 4 Monthly Water Flow, Individual Fields
Figure 5 Weir Volume Flow, (B) Field
Figure 6 Weir Volume Flow, (A) Field
Figure 7 Weir Volume Flow, System Totals
Figure 8 Tap Water Analysis
Figure 9 Piezometer Water Levels, April 2, 1936
Figure 10 Piezometer Water Levels, August 5, 1987
Figure 11 Site Location Map - Piezometer Network
Figure 12 Water Levels, Pumping Well D7
Figure 13 Changes in Chemical Parameters Along Treatment Channel BA
Figure 14 Changes in Chemical Parameters Along Treatment Channel BA
Figure 15 Contaminant Concentrations Along the Grass Treatment Field (A)
Figure 16 Contaminant Concentrations Along Treatment Channel BA

LIST OF TABLES

Table 1 Monthly Water Pumping Records
Table 2 Weir Water Flow Measurements
Table 3 Bedrock Aquifer Chemistry
Table 4 Major Ions in Water Chemistry
Table 5 Water Levels in Pumping Well D7
Table 6 Water Analysis, Homeowners Wells
Table 7a Water Analysis, Overburden Piezometers
Table 7b Water Analysis, Bedrock Piezometers
Table 8 Treatment Field Chemistry

EXECUTIVE SUMMARY

The rehabilitation of aquifers which have been contaminated with organic compounds is a new and important science in Ontario. Many of the hydrogeological, geochemical and engineering principles which now permit remediation of groundwater supplies have only been developed within the past decade. Much of the present technology was developed for other types of wastewater treatment, and is extremely expensive or technically unsound when applied to groundwater rehabilitation problems.

This study funded by the Ministry of the Environment provides an assessment of the performance of a relatively low cost overland flow, biological treatment process to effectively reduce levels of organic compounds in gasoline contaminated groundwater to acceptable concentrations for discharge into surface waters.

The remedial work involved the installation of a purge well near the centre of the contaminant plume and its operation at a flow rate of 325 litres/minute. This paper provides details of the construction of the overland flow, biological treatment system and an assessment of the performance of the system during the first twelve months of operation. Benzene concentrations of 100-150 ug/L, toluene at 10-30 ug/L and naphthalene at 30 ug/L were characteristic early concentrations in the purge well effluent. At the treatment system outlet, the contaminant concentrations are generally below laboratory detection levels (1 ug/L). Throughout 1987, the quality of the discharge water remained high and no significant (contaminant related) stress was observed in the treatment vegetation. Thus, preliminary results indicate the system is suitable for long term treatment.

Levels of benzene, toluene, ethylbenzene, xylene and phenols in water from the purge well show a steady decline in concentration as pumping time increases.

The methods tested in this report should be applicable to a wide range of groundwater rehabilitation problems associated with spills, landfill operations and remedial undertakings. However, the research to date is solely applicable to gas spill problems.

1.0 INTRODUCTION

Water and Earth Science Associates Limited (WESA) was contracted, in 1986, by A.E. Williams and Company Limited of Toronto to construct a surface treatment system in conjunction with a groundwater purging system to treat gasoline contaminated groundwater in the Hamlet of Delta, Ontario. A report written by WESA in March 1986 discussed, in detail, the nature of the gasoline spill, local geology and hydrogeology, methods used to investigate the gasoline spill and the chemical results of those investigations. A large section of that report dealt with various remedial treatment alternatives that could be implemented at Delta, to solve the groundwater contamination problem.

The construction of the treatment facility, its operational history during the first six months of use, water and air sampling procedures, and results have been previously described (WESA, 1987). The initial conclusions in the report were that the system is effective in halting and subsequently reversing the movement of hydrocarbon contaminants in the groundwater. Frequent periodic sampling had shown that the level of hydrocarbon contaminants entering the pumping well was decreasing with time.

This study funded by the Ministry of the Environment Research Advisory Committee, provides a more detailed assessment of the performance of the relatively low cost overland flow, biological treatment process, in effectively reducing levels of organic compounds in gasoline contaminated groundwater to acceptable concentrations for discharge into surface streams.

During the last two weeks of July 1987, an intensive two-week sampling program was carried out by WESA staff with the participation of the Ontario Ministry of the Environment (MOE). Utilizing an MOE mobile lab to provide short time, high volume turnaround for organic analysis, detailed sampling was conducted on nearby private wells, previously installed overburden and bedrock piezometers, as well as all parts of the treatment fields. Results show that water quality improvement is rapid in all parts of the treatment field. The results of the joint WESA-MOE field investigation were presented at the 1987 MOE Technology Transfer Conference in Toronto.

As part of the preparations for winter operation the grass field was shut down on November 18 1987. At that time, water flow through the vegetated channels was increased to maintain a fairly constant flow rate out of the cement exit notch.

During the last half of the year, the Delta facility operated effectively and essentially without problems.

2.0 BACKGROUND INFORMATION

Delta is located between Upper and Lower Beverly Lakes, along Highway 42, about 50 km northeast of Kingston (Figure 1). The first indication that a groundwater contamination problem existed in Delta came in 1976 when a resident complained to the Ministry of the Environment (MOE) that her water had acquired a petroleum taste and odour. After this complaint, a gasoline audit was carried out at the service station located immediately across the road (northward) from the contaminated well. A deficit of 4000-4500 litres (900-1000 gallons) of regular gasoline was discovered and shortly afterward the suspect tank was pressure tested. It was established that spillage at the fill lines, and possibly a loose fitting on the underground piping system, contributed a small volume of fuel to the ground water each time the tank was filled.

In June 1976, the MOE conducted a field investigation of the site, and concluded that the service station was the source of contamination. An activated carbon filtration treatment system was installed in the affected residence.

In 1980, a second case of groundwater contamination was reported to the MOE. This complaint came from the homeowners living immediately to the west of the first affected well. A treatment system was also installed at this location.

In 1982, WESA conducted a hydrogeological investigation of the area, as part of a preliminary engineering report for Delta, under the Ministry Individual Correction Services Program. Sampling from overburden piezometers installed downgradient of the problem area revealed that the gasoline contamination problem was much more extensive than had been previously realized. The contaminant plume was estimated to be 550 m long, 350 m wide and 60 m deep (plume boundaries defined by the lower taste and odour thresholds). It was estimated that a total of between 7,700 and 34,000 litres (1,700 - 7,500 gallons) of fuel had been lost, and that an estimated 173 million litres (38 million gallons) of groundwater were polluted. Granulated activated carbon (GAC) treatment units were supplied to all homeowners as soon as the presence of hydrocarbons became apparent in their water.

3.0 SITE DESCRIPTION

3.1 Geology

Delta is located on the eastern margin of the Frontenac Axis, a physiographic subregion of the Precambrian Shield. This section of the axis comprises carbonate metasedimentary rocks, with the predominant rock types being marble and skarn.

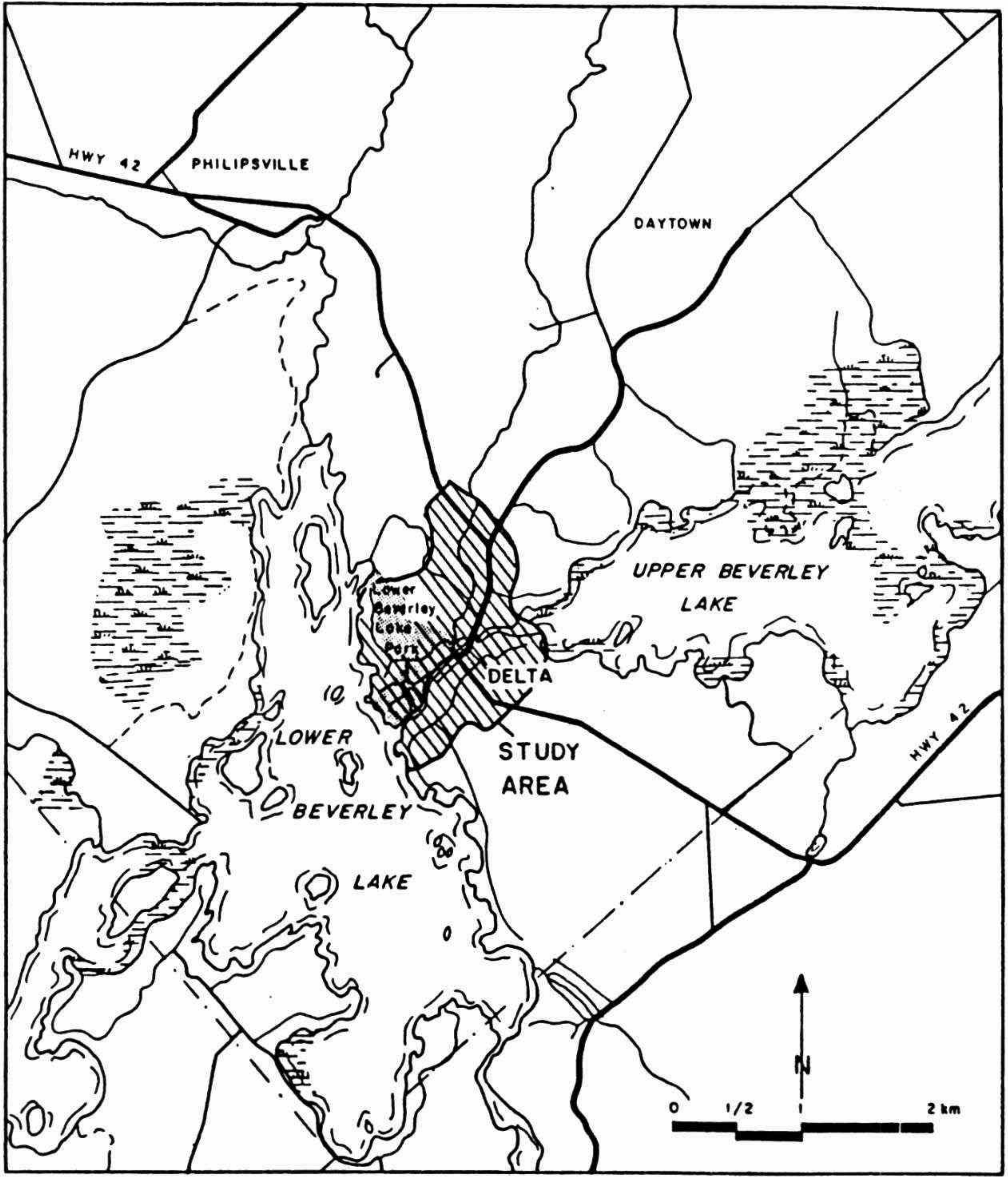


FIGURE 1

LOCATION AND ACCESS MAP

HAMLET OF DELTA, ONTARIO

WATER AND EARTH SCIENCE ASSOCIATES LTD.

Nepean sandstone unconformably overlies the marble in the northern portion of the town. Marble is present at surface near the centre of the hamlet, on the banks of the Delta Creek.

The surficial materials comprise a sequence of sands and gravels overlain by lacustrine clay and silt. This entire sequence is present in the northern part of the study area, where depressions in the bedrock contain the coarser sediments. To the south, where the bedrock surface is more regular, the coarse material is absent.

3.2 Drainage

Delta Creek runs through the centre of the hamlet and connects Upper and Lower Beverly Lakes. The creek exhibits a seasonably variable flow which can be very low in the summer months.

Foundry Creek, also known as Cowan Creek, flows along the west side of the study area and shows a similar discharge cycle to that of Delta Creek. Foundry Creek appears to be a "gaining" stream; ie. it is fed by groundwater from the sand and gravel deposits through which it has eroded.

4.0 TREATMENT FIELD DESIGN

An assessment of various remedial technologies was undertaken to determine a feasible approach to remediation of the groundwater aquifer (WESA, 1986). The assessment indicated that a purge well, in conjunction with an overland flow biological treatment facility, was the most cost effective approach to cleanup. Aquifer testing indicated that the plume could be controlled by operating one or two purge wells at a total discharge rate of no more than 11.4 L/sec (150 IGPM). The biological treatment system comprises a surface aeration unit, (to promote aeration of the water, volatilization of the hydrocarbons and organics, and precipitation of metal oxides), iron/organic precipitation channels, a grass field (where biological remediation of the discharge occurs), and a marsh treatment area for final effluent polishing.

The construction phase was completed in December, 1986, and the system was ready for operation in January, 1987. A 20.3 cm (8 in.) diameter purge well, 54 m (177 ft.) deep, was installed midway along the northern boundary of the treatment facility. The purge well was situated where piezometer and private well sampling had indicated the greatest hydrocarbon contamination was present. A fourteen horsepower submersible turbine pump was installed in the purge well to move contaminated groundwater to the treatment fields.

After passing through a flow control building, the groundwater stream is split for passage to two treatment fields, aerated by two sprinkler fountains and then collected in two concrete distribution troughs (Figure 2). One of the troughs empties onto a gently sloped grass field, and the other into 3 treatment channels (denoted, BA, BB, BC) each containing a different type of vegetation (Figure 2). This design permits the pollutant attenuating capacities of the various types of vegetation to be compared.

Each sprinkler fountain consists of a 7.6 cm (3 in.) diameter PVC header pipe which feeds several small diameter brass sprinkler nozzles. These nozzles are located at regular intervals along the feeder pipe. At the spillover lip of each distribution trough, coarse gravel forms a "rip rap" structure. This feature is designed to increase the physical agitation of the contaminated water, thereby maximizing its atmospheric exposure.

The grass field (A) was designated an "overland flow" field, and was prepared by spreading topsoil over the existing soil, and grading it uniformly to a maximum 2% slope. The field was then rototilled, fertilized, and seeded to give a vegetated cover. Three grasses were planted: Phalaris arundinacea (Reed Canary Grass), glyceria grandis (Manna grass) and Calamagrostis canadensis (Bluejoint). During the operation of the grass treatment field, the ground is covered with between 1 and 2 cm of water. The depth of the water varies slightly across the field due to local topographic irregularities.

Field B comprises three channels, each containing different kinds of vegetation. The first channel (BA) was filled with cut hay to a depth of 20 cm. This channel provides information about the attenuation potential of decaying vegetation. The second channel (BB) was seeded with Hydrocharis morus-ranae (Frog-bit), a floating and strongly stoloniferous species. These plants form extensive, fibrous roots which hang downward in the water. The third channel (BC) was vegetated with narrow-leaved emergent plants (mainly grasses). The principal species comprised Calamagrostis canadensis (Bluejoint), Phalaris arundinacae (Reed Canary Grass), and Poa palustris (Swamp Meadow Grass).

After passing over the grass field and through the vegetated channels, the treated discharge water collects in an artificially created marsh, which contains mainly cattails (Lythrum salicaria) and frog-bit (Carex crinellii). Other vegetation present include; Sagittaria cuneata (Arrowleaf), Cicuta bulbifera (Bulb-bearing Water Hemlock), and Alisma plantago aquatica (Water Plantain). From the cattail marsh, water drains into Foundry Creek.

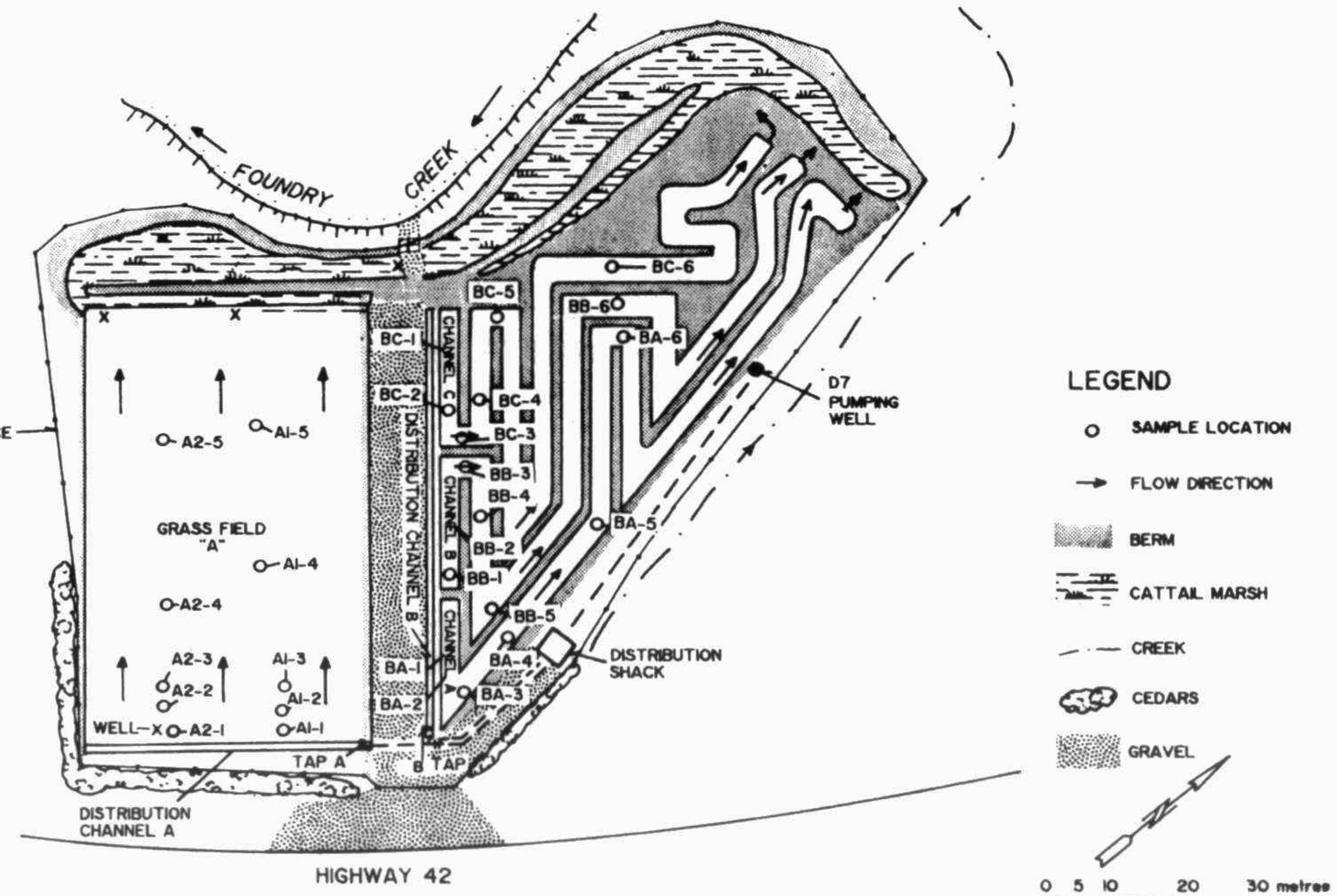


Figure 2

SITE PLAN

DELTA, ONTARIO

5.0 TREATMENT FACILITY RESULTS

5.1 Operational Phase

On January 15, 1987, after initial field tests and calibration, the system was activated. Pumping continues 24 hrs/day, 7 days/week. The channel system, (B Field) was initially opened for winter operation. The system operated during the winter with little difficulty. A storm-induced power failure resulted in a system shut-down and subsequent freezing during February 1987. Groundwater was used to thaw the frozen parts and the system was reactivated on February 23, 1987. There was only one other notable interruption of the treatment system; in early April 1987, Field B was shut down for maintenance.

Fields A and B were placed into continuous operation on April 15, 1987. There were very few interruptions during either the summer or fall of 1987. Table 1 summarizes the monthly pumping data through both treatment fields. Operational time capacity shows a substantial improvement in the final months of the year with virtually no maintenance required and the only unanticipated shutdown occurring as a result of an ice storm induced power failure in early December. The system was reactivated without difficulty and has been operating continuously since then.

Each of the two distribution troughs were originally designed to operate with 38 aeration nozzles. To avoid too coarse an aerating mist and to keep the height of the spray controllable, one half of the nozzles in the B distribution trough, and about one quarter of the nozzles in the A trough were capped.

The vegetated channels (B Field) may be operated year-round. However, the grass field (A Field) must be closed during the winter months because snow and freezing conditions cause channelling and localized erosion that disrupts the flow field. The grass field was shut down for the winter on November 18, 1987.

5.1.1 Water Flow: A Field

Table 1 shows that in 1987, almost 12,100,000 gallons (44.3% of the total annual volume) were pumped through the 27 nozzles of the A Field distribution trough. Initially the pumping rate for this system was about 46 IGPM, though early in the summer this was lowered slightly to avoid interference with neighbouring wells. Dry summer weather led to a further decrease in pumping rate to between 36 and 38 IGPM. In November the pumping rate was raised to its earlier level of 46 IGPM.

5.1.2 Water Flow: B Field

In 1987, almost 15,200,000 gallons were pumped through the 19 nozzles of the B Field distribution pipes. During the months of January and February, the pumping rate was about 50 IGPM. This volume of water was reduced during the summer to between 30 and 33 IGPM. After the grass field (Field A) was shut down in mid-November the pumping rate was again set at about 55 IGPM.

5.1.3 System Water Flow

Figure 3 shows the cumulative flow through the system for 1987. After the initial problems with water freezing due to storm induced power failures, the system was slightly modified, resulting in a more stable operation. The individual field monthly flow volumes are shown graphically in Figure 4. During the period that both systems are in operation, slightly more than 55 percent of the total pumped water was diverted to the grass field.

5.1.4 V-Notch Weir Water Flow

During the spring maintenance period, while repairs were made to the berms damaged during winter operations, V-notch weirs were installed at the end of all three channels in the B Field, at the end of the water collection trench of the grass field, and in the cement exit notch where the water spills from the cattail marsh into Foundry Creek. All notches were constructed with a "V" of 90 degrees, except the exit notch which was cut at 60 degrees. The height of the water passing across the notch was measured with a ruler and the flowrate of water in IGPM was then determined from standard tables.

Table 2 summarizes the results of the weir flow measurements. Figure 5 shows the volume of water passing from the channels of the B field into the cattail marsh. Figure 6, shows the volume of water flowing off the grass (A) field expressed both as IGPM and as a percent of the total amount pumped. The difference between the total volume of water pumped, and the volumes leaving the fields are attributable to infiltration and evaporation.

An average of 45 percent of the total water volume flows across the grass field (A) and into the marsh. More than 70 percent of the pumped water moves out of the channels into the cattail marsh. These data indicate that infiltration/evaporation losses are considerably higher on the grass field than in the channels. This finding is not surprising since the total surface area of water is in contact with the atmosphere and sediment is greater for a flat field than a channel.

Table 1

Delta Pumping Record SYSTEM 1 / (A) GRASS FIELD : Monthly Summary

	Estimated Reading Start (gal)	End (gal)	Approx. Monthly Total (gal)	Approx. Operational Time (Days)	Approx. Average Rate (IGPM)	Monthly Operating Capacity (%)
JANUARY	902	929	27	0.0	0	0
FEBRUARY	929	238900	237971	3.9	42	14
MARCH	238900	240400	1500	0.0	0	0
APRIL	240400	1384400	1144000	17.4	46	58
MAY	1384400	3004400	1620000	26.2	43	84
JUNE	3004400	4496700	1492300	25.4	41	85
JULY	4496700	6157200	1660500	27.5	42	89
AUGUST	6157200	8093700	1936500	31.0	43	100
SEPTEMBER	8093700	9574700	1481000	28.9	36	96
OCTOBER	9574700	11279700	1705000	31.0	38	100
NOVEMBER	11279700	12332725	1053025	17.5	42	58
DECEMBER			Shut Down	0.0	0	0
1987 TOTALS			12093852			

Notes: All February water diverted to B field
Yearly totals exclude February
System Shut down for Winter on November 18, 1987

Delta Pumping Record SYSTEM 2 / (B) CHANNELS : Monthly Summary

Month	Estimated Reading Start (gal)	End (gal)	Approx. Monthly Total (gal)	Approx. Operational Time (Days)	Approx. Average Rate (IGPM)	Monthly Operating Capacity (%)
JANUARY	1749	1209900	1208151	17.2	49	62
FEBRUARY	1209900	2180900	971000	13.1	51	47
MARCH	2180900	2231135	50235	0.8	47	3
APRIL	2231135	3080600	849465	16.3	36	54
MAY	3080600	4207100	1126500	25.5	31	82
JUNE	4207100	5360700	1153600	25.4	32	85
JULY	5360700	6644200	1283500	27.6	32	89
AUGUST	6644200	8086200	1442000	31.0	32	100
SEPTEMBER	8086200	9352600	1266400	28.9	30	96
OCTOBER	9352600	10808200	1455600	31.0	33	100
NOVEMBER	10808200	12672100	1863900	29.9	43	100
DECEMBER	12672100	14963500	2291400	28.9	55	93
1987 TOTALS			15199722			

Note : Yearly totals include February water diverted from A field

Delta Pumping Record SYSTEM TOTALS : Monthly Summary

	Estimated Reading Start (gal)	End (gal)	Approx. Monthly Total (gal)	Percent of Flow on A Field	Percent of Flow on B Field
JANUARY	2651	1210829	1208178	0	100
FEBRUARY	1210829	2419800	1208971	0	100
MARCH	2419800	2471535	51735	3	97
APRIL	2471535	4465000	1993465	57	43
MAY	4465000	7211500	2746500	59	41
JUNE	7211500	9857400	2645900	56	44
JULY	9857400	12801400	2944000	56	44
AUGUST	12801400	16179900	3378500	57	43
SEPTEMBER	16179900	18927300	2747400	54	46
OCTOBER	18927300	22087900	3160600	54	46
NOVEMBER	22087900	25004800	2916925	36	64
DECEMBER	25004825	27296200	2291400	0	100
1987 TOTALS			27293574		

Figure 3

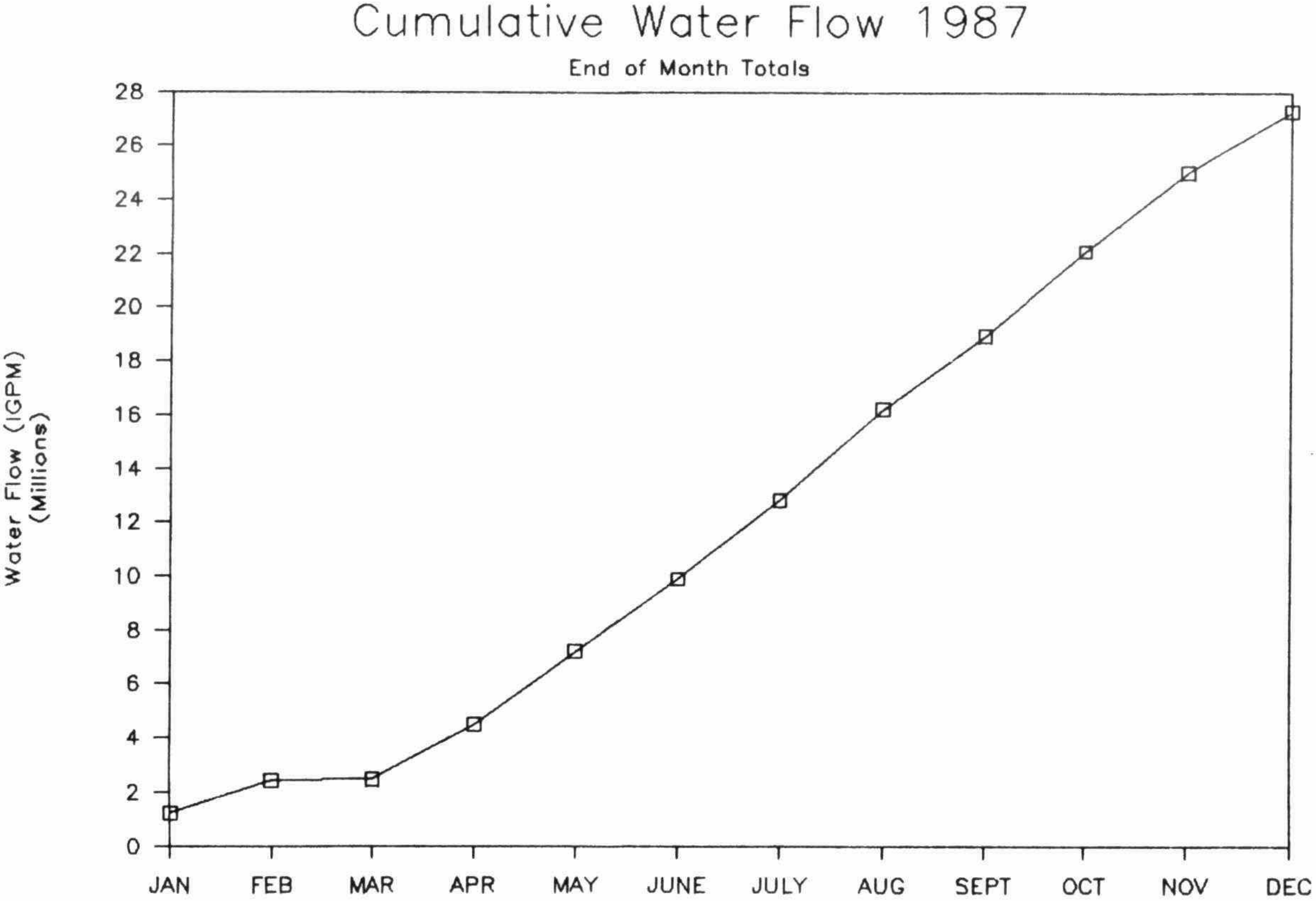

Cumulative Water Flow 1987
End of Month Totals
Water Flow (IGPM)
(Millions)
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC

Figure 4

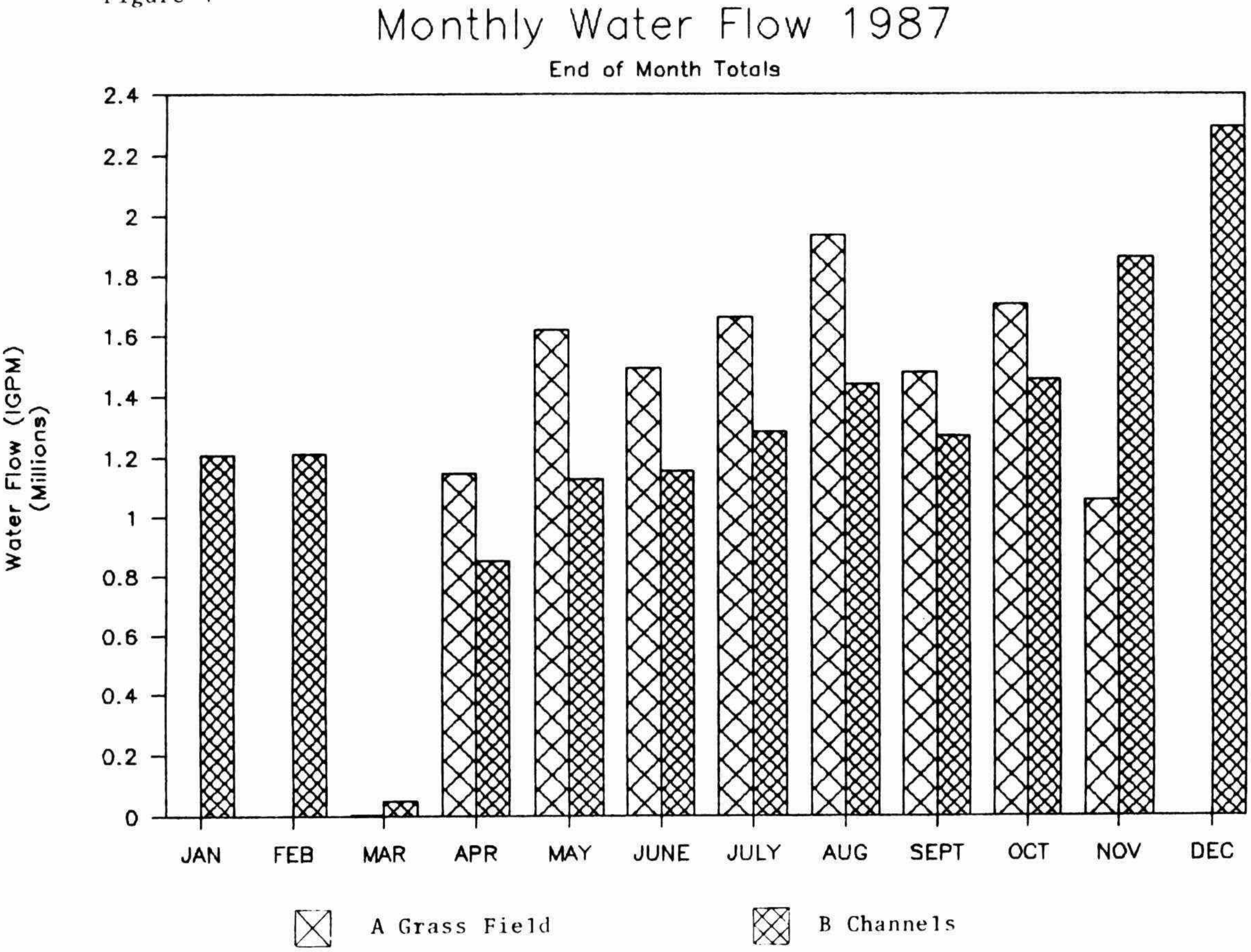

Monthly Water Flow 1987
End of Month Totals
Water Flow (IGPM) (Millions)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
A Grass Field
B Channels

Table 2

DELTA WEIR WATER FLOW MEASUREMENTS - 1987

		B Field Channels						A Field (Grass)			Cement Exit Notch		
Date	Days Elapsed	End A Channel (IGPM)	End B Channel (IGPM)	End C Channel (IGPM)	Total Flow All Channels (IGPM)	Average Pumping Rate (IGPM)	Percent of Pump Rate %	Water Flow (IGPM)	Average Pumping Rate (IGPM)	Percent of Pump Rate %	Water Flow (IGPM)	Average Pumping Rate (IGPM)	Percent of Pump Rate %
04-May		2.5	2.1	13.9	18.5	28	66	13.9	38	37	-	66	-
18-May	14	4.4	4.4	14.3	23.1	32	72	-	42	-	-	74	-
27-May	23	7.4	7.4	8.9	23.7	32	74	22.9	41	56	-	73	-
28-Jul	85	5.0	4.1	13.9	23.0	32	72	12.1	32	38	23.2	64	36
05-Aug	93	4.1	4.1	14.3	22.5	33	68	15.6	34	46	26.7	67	40
19-Aug	107	5.0	6.0	9.5	20.5	33	62	15.6	37	42	27.0	70	39
23-Sep	142	0.0	1.1	19.7	20.8	27	77	7.5	35	21	14.7	62	24
18-Nov	198	5.5	10.1	10.1	25.7	36	71	13.6	42	32	25.0	78	32
02-Dec	212	10.1	12.8	10.3	33.2	55	60	Shut Down	Shut Down	Shut Down	20.8	55	38

Figure 5

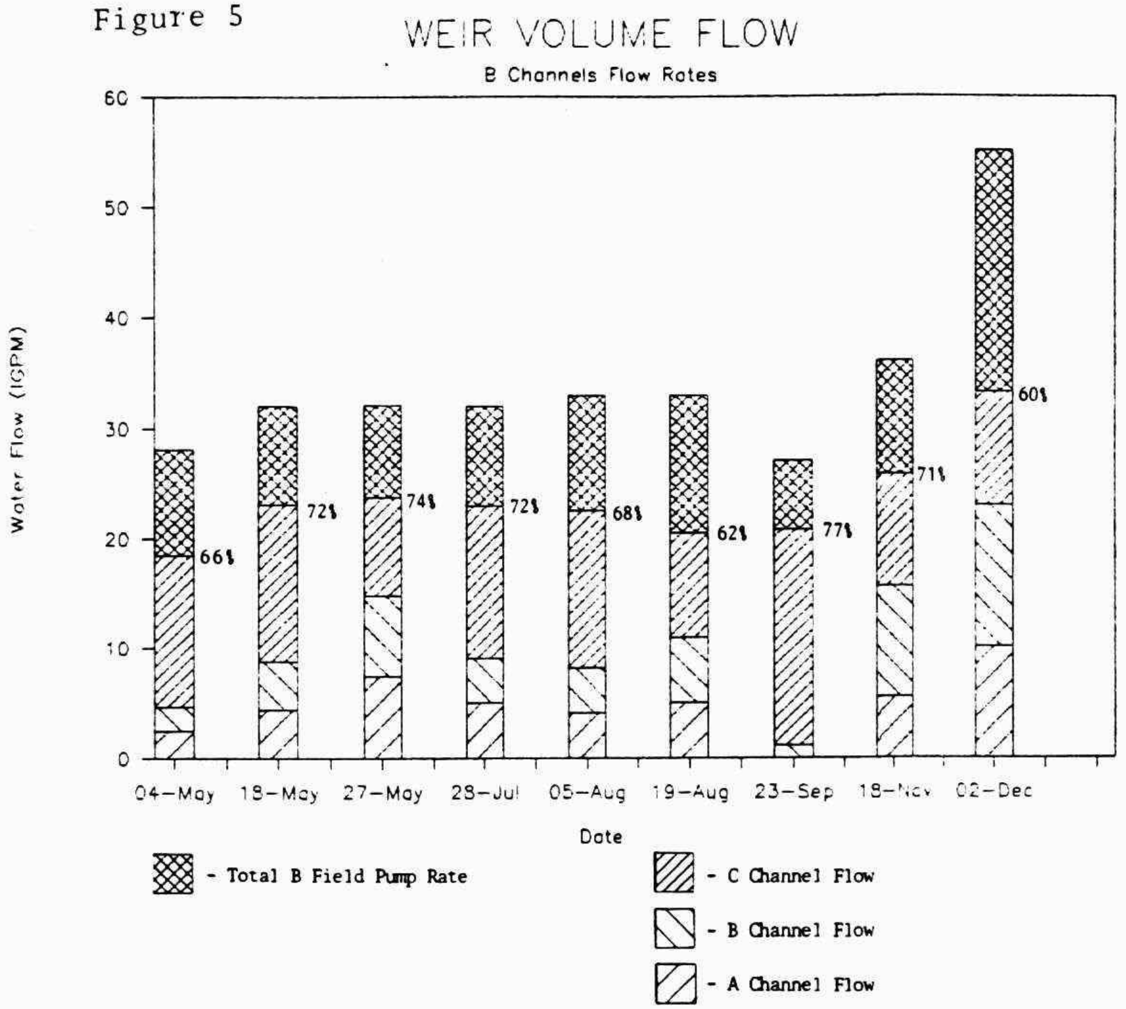
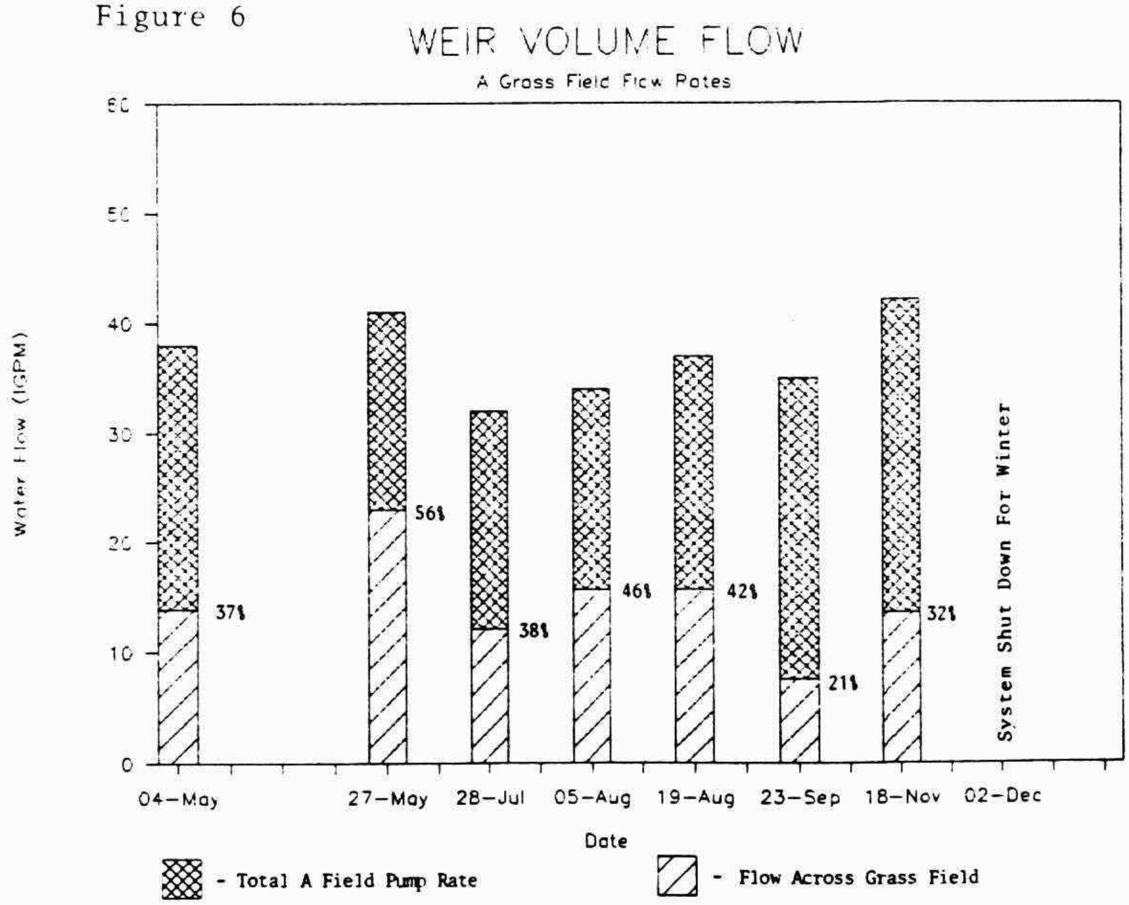


Figure 6



Variations in the volumes of water passing through the channels in B Field were initially due to irregularities in the level of the spillage lip of the distribution trough. Early in the summer, additional notches were cut in parts of the lip balancing the flow to the three channels.

Figure 7 shows the results of measurements made at the cement exit notch. The volume of water leaving the treatment system and passing over the spillway into Foundry Creek is less than 40 percent of the total volume pumped out of the ground. The greatest loss (76 percent) was observed in late summer when precipitation was unusually low.

5.2 Water Quality Sampling

Throughout the year water quality samples were obtained from the treatment field as specified in the Certificate of Approval (Appendix A). Samples were also obtained from the surrounding residential wells at regular intervals as part of the on-going monitoring program. This program was designed to measure contaminant concentrations, monitor plume progress, and test the effectiveness of the granulated activated carbon (GAC) filters. The filters were placed on domestic water supplies to remove dissolved hydrocarbons.

Samples were obtained and analysed by methods consistent with the USEPA 624 protocol for volatile organics (benzene, ethylbenzene, toluene and xylene) and USEPA 625 protocols for the non-volatile acid-extractable base neutral fractions (polycyclic aromatic hydrocarbons (PAH) and napthtalene). Iron analyses were obtained using the standard protocol followed by the MOE for cation sampling. Samples were filtered through 0.45 um millipore filter and acidified with HNO_3. Samples for total phenols were preserved with $CuSO_4$ and H_3PO_4. All samples were refrigerated prior to shipment to a contract laboratory.

Bondar Clegg and Company Limited conducted analyses for inorganic substances and phenols. Dr. John Poland of Queen's University was employed for the analysis of volatile organics and some inorganic samples. Mann Testing Laboratories were employed for the specialized PAH analyses.

The purge well at the treatment site was completed in the most contaminated section of the bedrock aquifer. Consequently, gasoline contamination is still present there. However, the improvement in the condition of the aquifer is apparent in Figure 8. The concentrations of all the major aromatic contaminants show a steady decline in concentration through 1987. It is anticipated that the contaminant levels will continue to

Figure 7

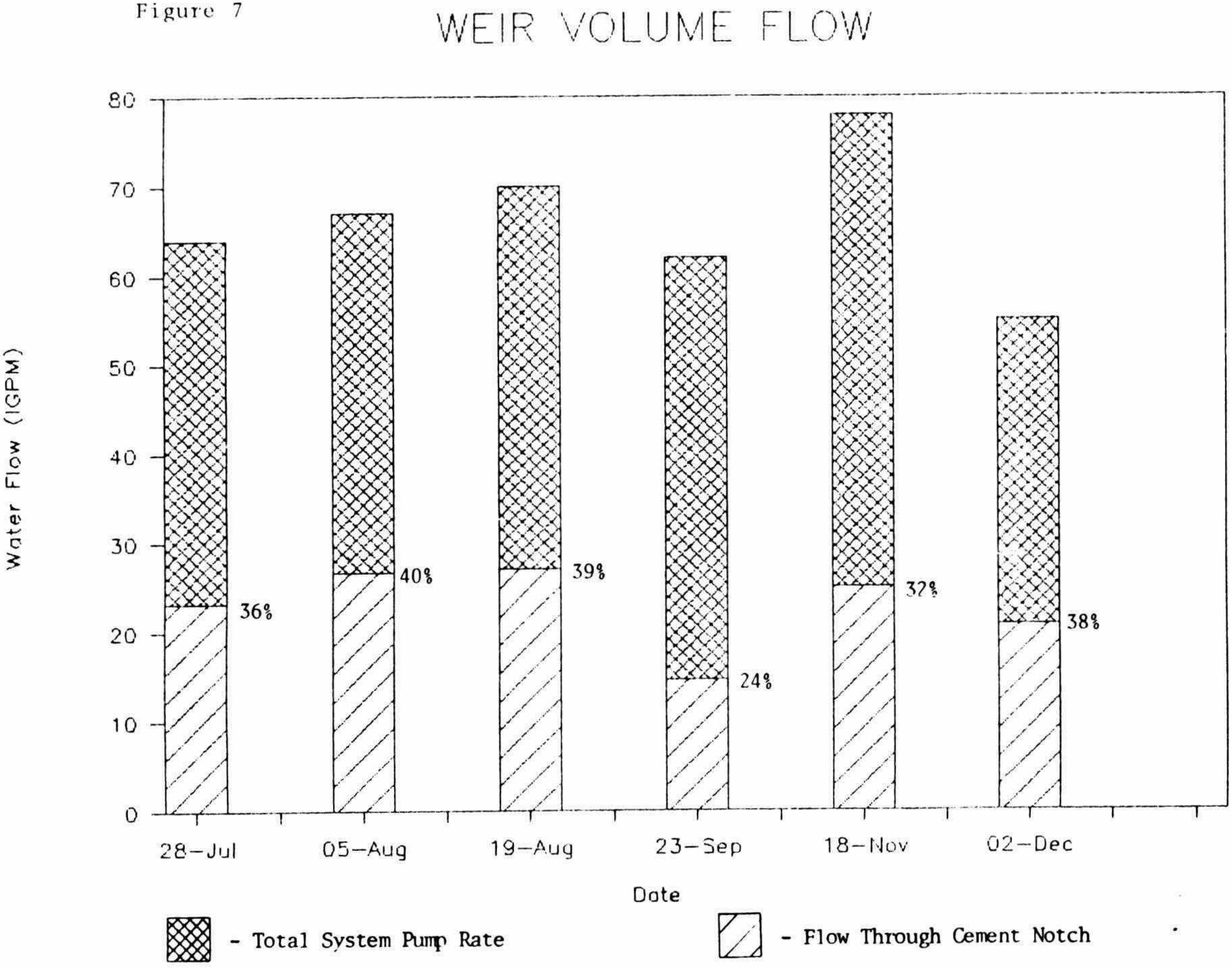
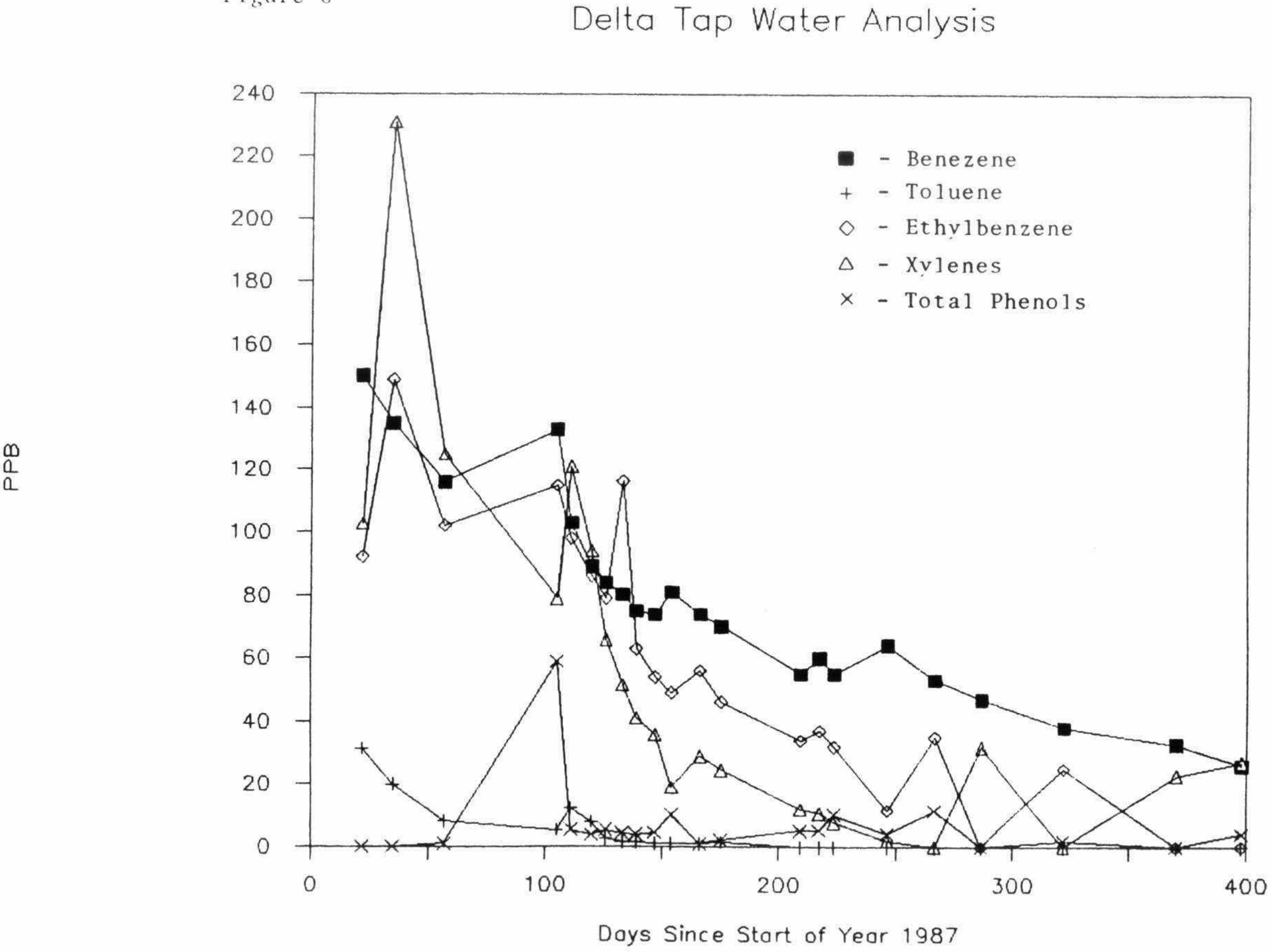

WEIR VOLUME FLOW
Water Flow (IGPM)
80
70
60
50
40
30
20
10
0
36%
40%
39%
24%
32%
38%
28-Jul
05-Aug
19-Aug
23-Sep
18-Nov
02-Dec
Date
▩ - Total System Pump Rate
▨ - Flow Through Cement Notch

Figure 8


Delta Tap Water Analysis
■ - Benezene
+ - Toluene
◇ - Ethylbenzene
△ - Xylenes
× - Total Phenols
PPB
240
220
200
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
Days Since Start of Year 1987

decrease with time but at a reduced rate. This trend will be recognizable as tailing of concentration verses time data. The effect of "tailing" is that longer pumping times will be necessary to purge the aquifer than would be predicted from initial cleanup rates. Continued monitoring will provide the necessary information for deciding when the purging is complete.

A summary of the year-long bedrock aquifer chemical results are shown on Table 3 and inorganic analyses conducted in 1987 are given in Table 4. Detailed results are shown in Appendix B. The analyses are grouped according to location site and are listed in sequential order. Samples representative of the aquifer water were obtained from the B-Tap which is located at the B Field distribution trough. Water drawn from this tap is assumed to be representative of raw, contaminated water from the well. This flow has not yet contacted the air and is under pressure. Therefore, volatilization of organic compounds is not a concern. Iron precipitation or other changes in inorganic chemistry are unlikely as well. The A-Tap is located at the A Field distribution trough and was sampled later in the summer. During the initial six month operational period, samples were taken on a weekly basis.

Initial concentrations of untreated effluent (B-Tap) were on the order of 150 ppb benzene, 31 ppb toluene, 92 ppb ethylbenzene, 102.6 ppb xylene, 30.6 ppb naphthalene, 106.4 ppb trimethylbenzene, and 1.9 ppm iron, and 4 ppb total phenol. The last analytical results available show an untreated water concentration decrease of over 80% for benzene and ethylbenzene, and a decrease of over 95% for toluene. Concentrations of influent waters and the trend in concentration with time are shown on Figure 8.

Data from other sampling locations downstream of the distribution troughs, indicate that there is a reduction in contaminant concentrations to below instrument detection limits.

With the exception of one sample collected in early spring, that contained trace levels of phenols, no gasoline-derived contaminants have been detected leaving the site. In addition, iron concentrations drop from about 2 ppm in the untreated water, to <0.1 ppm in the discharge water.

5.3 Homeowner Water Quality

Sampling of the Delta homeowners water for benzene contamination (demonstrated in previous reports to be a reliable indicator of gasoline contamination at this site, WESA, 1986) has been done at regular intervals over the past three years. Appendix C summarizes the results of the sampling.

Table 3

DELTA BEDROCK AQUIFER WATER CHEMISTRY (Sample collected at tap)

Sample Date	Location	Analyst	Benzene PPB	Toluene PPB	Ethylben PPB	Xylene PPB	T Phenol PPB	Fe PPM	Napthal. PPB	Trimetben PPB	D10 Anthracene
1-22-87	B - Tap	Mann Labs	150.2	31.3	92.1	102.6	NA	NA	30.6	106.4	
2-04-87	B - Tap	J. Poland	135.0	20.0	149.0	231.0	NA	NA			
2-26-87	B - Tap	J. Poland	116.0	8.1	102.0	125.0	1.0	0.90			
4-15-87	A - Tap	Poland/Mann	133.0	5.3	115.0	79.0	59.0	1.20	4		69%
4-21-87	B - Tap	J. Poland	103.0	12.3	98.0	121.0	5.4	1.90			
4-30-87	B - Tap	J. Poland	89.0	7.9	86.0	94.0	3.8	1.78			
5-06-87	A - Tap	J. Poland	84.0	2.8	79.0	66.0	5.4	2.00			
5-13-87	B - Tap	Mann/Poland	80.3	1.4	116.3	51.6	4.3	0.15		49.8	90%
5-19-87	B - Tap	J. Poland	75.0	1.4	63.0	41.0	3.9	1.27			
5-27-87	A - Tap	J. Poland	74.0	1.0	54.0	36.0	4.4	1.44	7		
6-03-87	A - Tap	J. Poland	81.0	1.0	49.0	19.0	10.2	2.53			
6-15-87	B - Tap	P/BC/M	74.0	1.1	56.0	29.0	1.0	0.26	4		103%
6-24-87	A - Tap	J. Poland	70.0	1.6	46.0	24.5	2.1	1.25			
7-28-87	B - Tap	J. Poland	55.0	<1.0	34.0	11.9	5.1	NA			
8-05-87	B - Tap	J. Poland	60.0	<1.0	37.0	10.8	5.2	1.20			
8-11-87	B - Tap	J. Poland	55.0	<1.0	32.0	7.8	10.2	1.14			
9-03-87	B - Tap	J. Poland	64.0	<1.0	11.5	1.9	4.2	1.88			
9-23-87	B - Tap	J. Poland	53.0	<1.0	35.0	<5.0	11.5	1.52			
10-13-87	B - Tap	J. Poland	47.0	<1.0	<5.0	32.0	NA	1.43			
11-18-87	B - Tap	J. Poland	38.0	<1.0	25.0	<5.0	2.0	1.57			
1-05-88	B - Tap	J. Poland	33.0	<1.0	<2.0	23.0	<1.0	1.34			
2-02-88	B - Tap	J. Poland	26.0	<1.0	<2.0	27.0	4.1	1.44			

Table 4 Major Ion Water Chemistry
(samples collected from BTAP - untreated water)

Element	1-1400-19-5-87	6-1400-19-5-87
Cl^-	74.4 ppm.	78.4 ppm.
NO_3^-	<1.0	1.8
NO_2^-	<1.0	<1.0
SO_4^-	40.5	42.6
Na	74	78
K	11.5	11.8
Ca	67	61
Mg	32.1	32.0
Cu	<0.05	<0.05
Cd	<0.02	<0.02
Zn	<0.02	<0.02
Co	<0.10	<0.10
Cr	<0.05	<0.05
Mn	0.20	<0.05
Ni	<0.10	<0.10
Pb	<0.05	<0.05

5.4 Hydraulic Response of the Aquifer

The purge test, conducted during September of 1985 demonstrated that physical control of the gradients in the sandstone marble aquifer could be exercised using a single purge well and could be maintained by pumping on the order of 80 IGPM from this well. The test illustrated that yields of this magnitude were possible from a single 200 mm (8 inch) diameter well and that well interference effects at this pumping rate would be minimal. This test also showed that gradient reversals at the plume front were feasible.

Purging of the aquifer from the treatment site, without reinjection appears to be causing the same conditions on the aquifer as those observed during the aquifer tests. A quasi-steady state drawdown condition has been obtained for the existing 80 IGPM pumping rate. By December 31, 1987, a total of 27.3 million gallons (124 million litres, 124,100 m^3) was pumped from the aquifer.

At the time the treatment facility was activated, gasoline contaminant plume was 550 m long, 350 m wide and approximately 60 m deep. The plume appeared to be moving on the order of tens of metres per year. An estimated 173,750 m^3 (38 million gallons) of groundwater had been contaminated above the drinking water objective adopted by the MOE, 10 ppb benzene. Twelve residences had intermittent or continuous gasoline contamination problems in their water supplies and required trucked water or GAC filter systems. On the order of 31 potential water supplies including a major commercial enterprise were in danger of being affected if the situation were left uncorrected.

A recent compilation of the drawdown data has shown that the gradient field is reversed and that a steady state flow regime is now established (Figures 9, 10). Piezometer water levels used to derive the drawdown data are listed in Appendix D. Figure 11 is an index map of piezometer location.

5.4.1 Drawdown in the Pumping Well

Throughout the operational period water levels in the pumping well, D7, were frequently monitored for drawdown. A summary of the drawdown against pumping rate is given in Table 5. Graphically the results are shown in Figure 12. The upper portion of the graph displays the pumping rate while the lower portion shows the corresponding drawdown. For most of the year drawdown below static level was between 4 and 5 metres. During the late summer, precipitation in the Delta region was below average and the drawdown in the pumping well began to increase. To avoid possible well interference effects with neighbouring homes, the

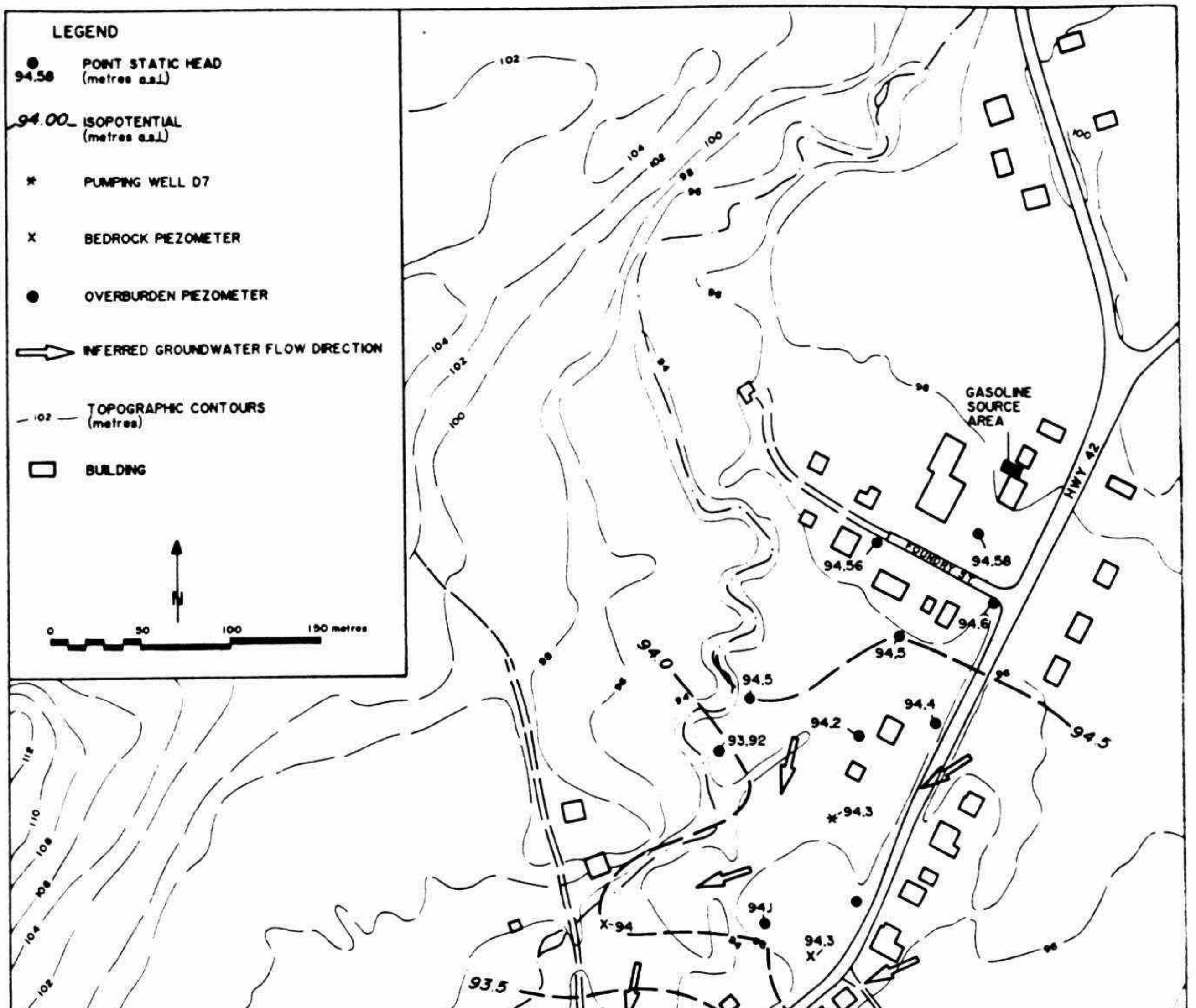


FIGURE 9

PIEZOMETER LEVELS - APRIL 2 1986
ELEVATION 79 - 91 METRES A.S.L.
DELTA, ONTARIO.

WATER AND EARTH SCIENCE ASSOCIATES LTD

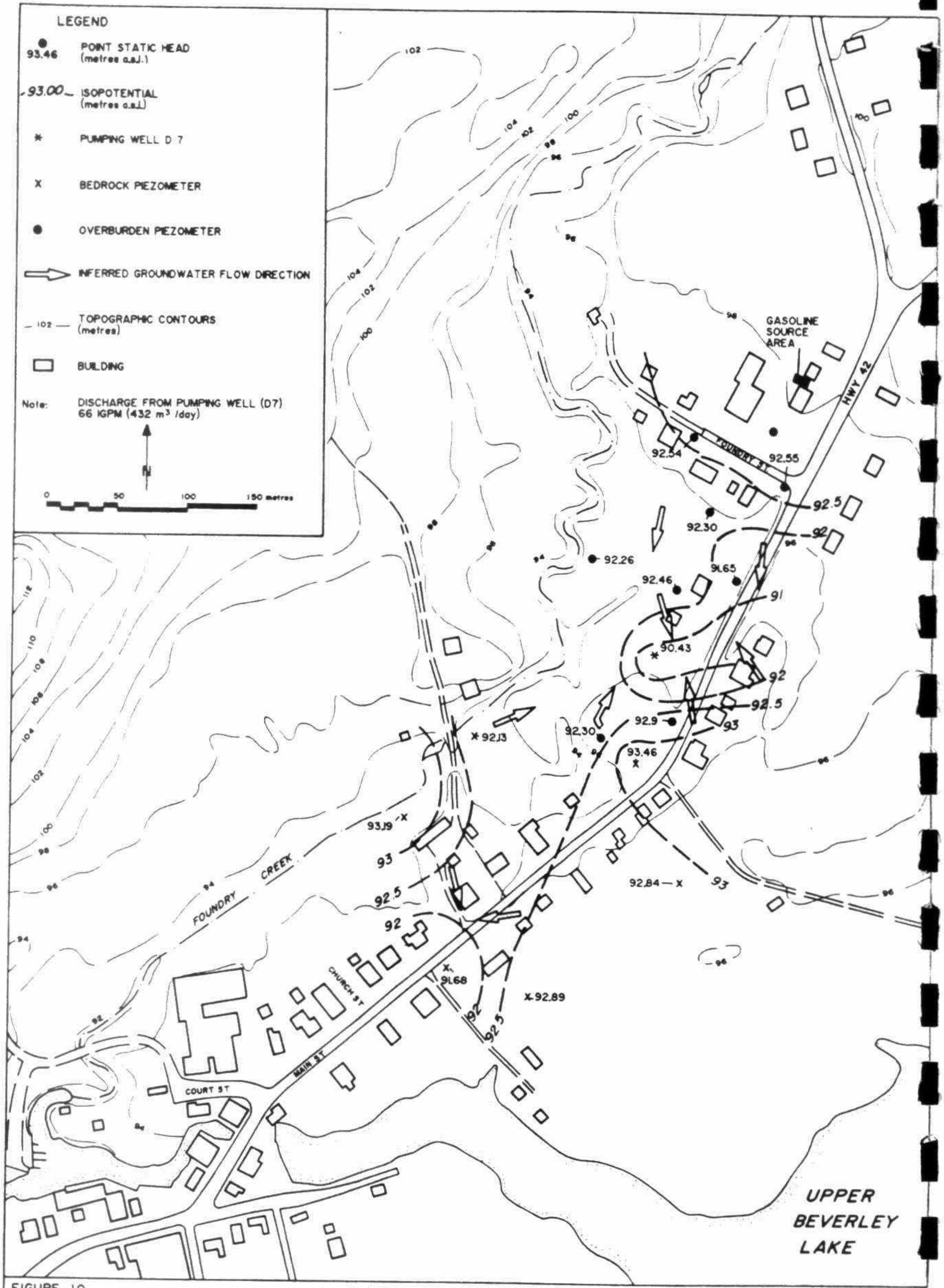


FIGURE 10

PIEZOMETER LEVELS - AUGUST 5 1987
ELEVATION 79 - 91 METRES A.S.L.
DELTA, ONTARIO.

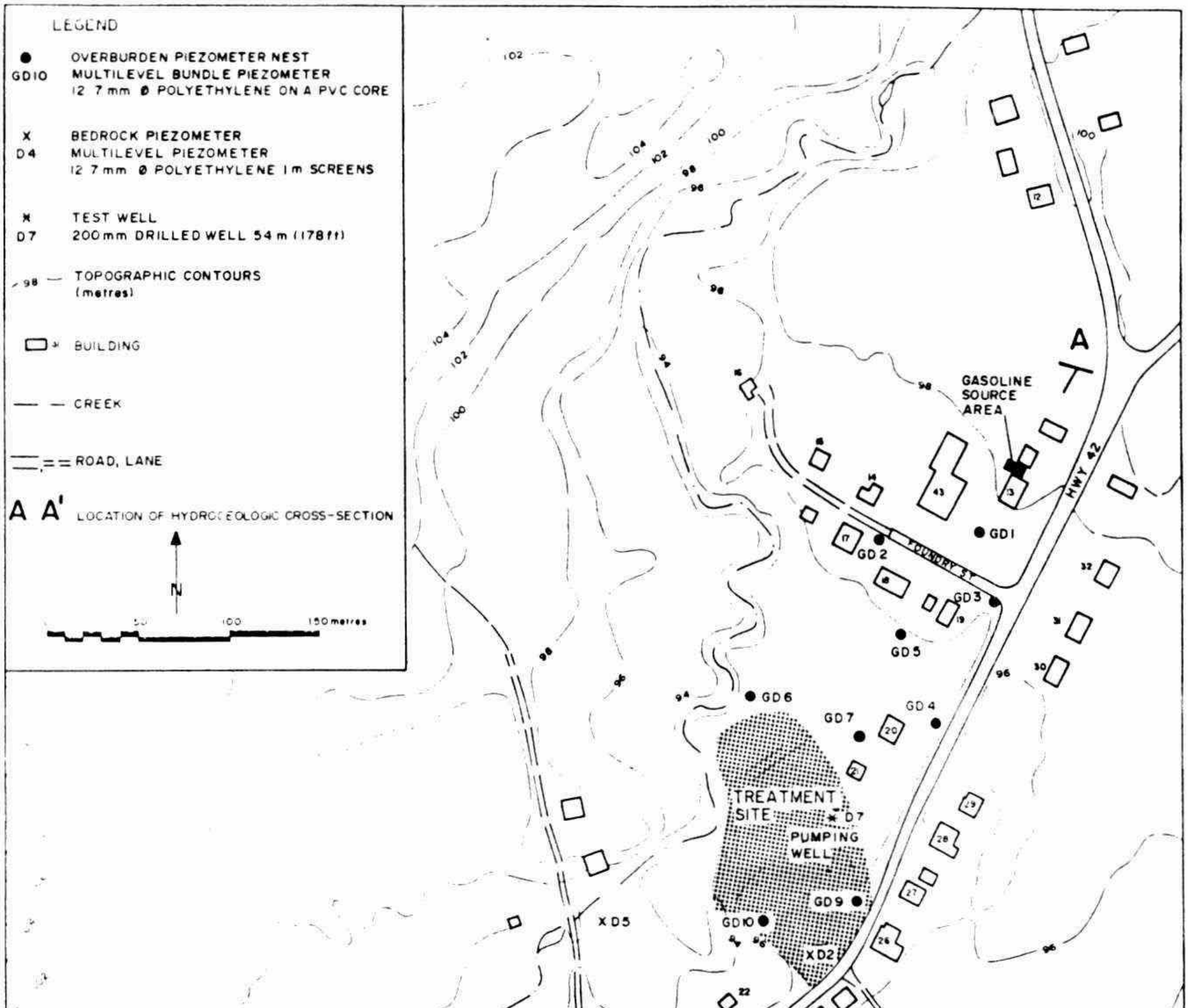


Figure 11
SITE LOCATION MAP - PIEZOMETER NETWORK

DELTA, ONTARIO

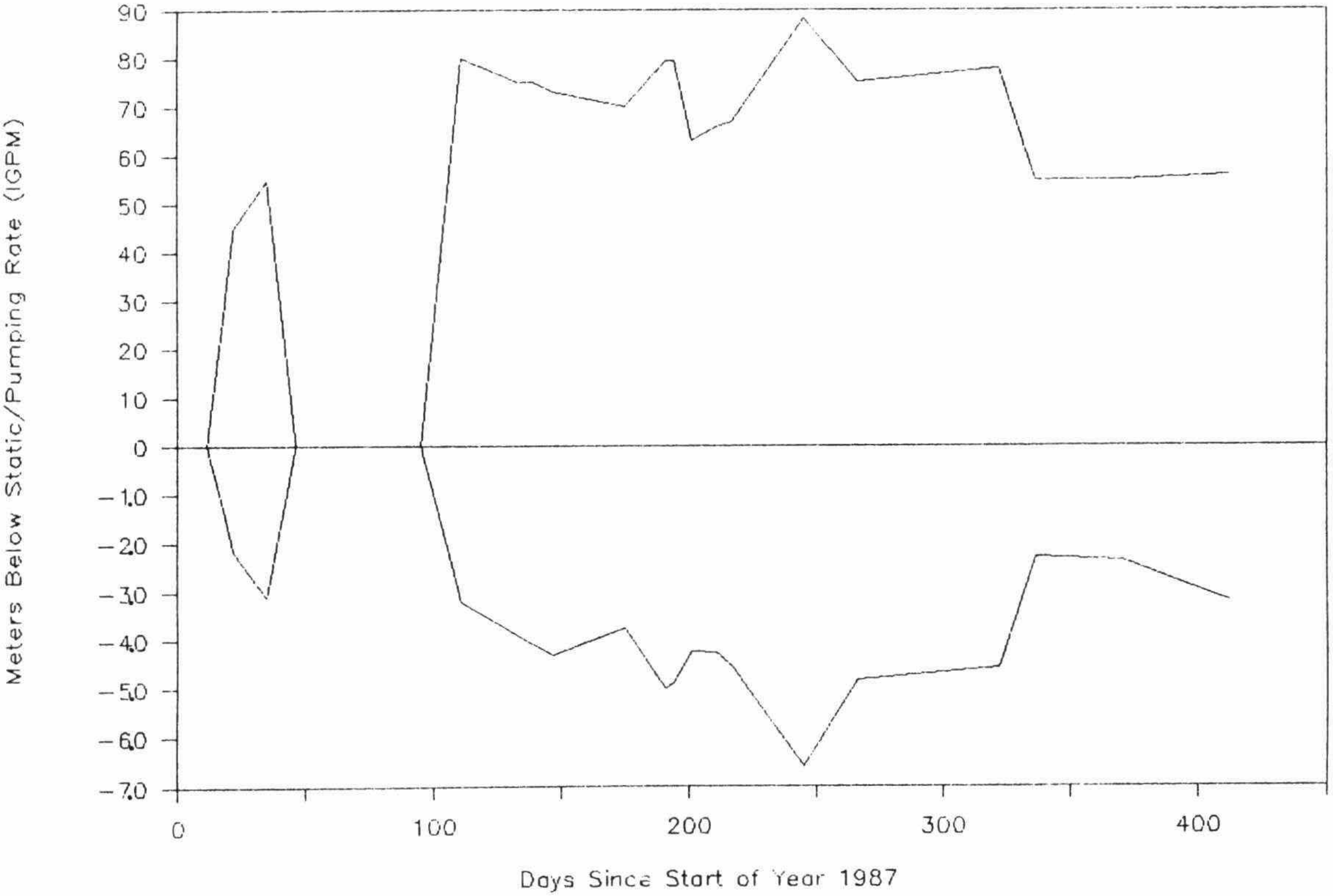
WATER AND EARTH SCIENCE ASSOCIATES LTD

Table 5

DELTA WATER LEVELS IN PUMPING WELL D7

Date	Days Elapsed	Cumulative Days	Water Level (m) (-TOC)	Below Static (m)	Below Static (ft)	Average Total Pumping Ra Previous 48 Hours (IGPM)	Notes
11-Jan-87		11	-1.40	0.00	0.0	0	
22-Jan-87	12	22	-3.58	-2.18	-7.2	45	Channels operational only
04-Feb-87	14	35	-4.51	-3.11	-10.2	55	"
15-Feb-87	12	46	-1.40	0.00	0.0	0	
05-Apr-87	50	95	-1.40	0.00	0.0	0	
21-Apr-87	17	111	-4.61	-3.21	-10.5	80	
13-May-87	23	133	-5.30	-3.90	-12.8	75	
19-May-87	7	139	-5.48	-4.08	-13.4	75	
27-May-87	9	147	-5.69	-4.29	-14.1	73	
24-Jun-87	29	175	-5.15	-3.75	-12.3	70	
10-Jul-87	17	191	-6.40	-5.00	-16.4	80	
13-Jul-87	4	194	-6.26	-4.86	-15.9	80	
20-Jul-87	8	201	-5.61	-4.21	-13.8	63	
30-Jul-87	11	211	-5.66	-4.26	-14.0	66	
05-Aug-87	7	217	-5.94	-4.54	-14.9	67	
02-Sep-87	29	245	-8.00	-6.60	-21.7	88	
23-Sep-87	22	266	-6.22	-4.82	-15.8	75	
18-Nov-87	57	322	-5.96	-4.56	-15.0	78	
02-Dec-87	15	336	-3.69	-2.29	-7.5	55	Channels operational only
05-Jan-88	35	370	-3.77	-2.37	-7.8	55	"
16-Feb-88	43	412	-4.57	-3.17	-10.4	57	"
04-Mar-88	18	429	-4.50	-3.10	-10.2	56	

Figure 12 Delta Water Levels : Pumping Well D7



pumping rate was reduced from about 88 IGPM to less than 70 IGPM. Increased precipitation in September permitted an increase in the pumping rate without the danger of well interference.

It can be seen in Figure 12 that not every increase in pumping rate has a corresponding increase in drawdown. This is in part the result of aquifer adjustment to dewatering caused by pumping and also by variations in the amount of recharge.

5.5 Air Quality Monitoring

Whenever a system which relies on volatilization of a contaminant is used, there is a risk that air emission guideline levels will be exceeded. This pertains to most air stripper operations and some bioreactors. To ensure that guidelines for volatile toxic organics, such as benzene, would not be exceeded during the initial aeration step of the process, a simple model was run using a standard air stripper designed for the influent flow rates and contaminant fluxes anticipated at the Delta site. This modelling, conducted by Canviro Consultants Limited, indicated that air quality criteria would not be exceeded by the proposed system.

As a precautionary step, in response to potential complaints of odours, three air samples were obtained from the site and the closest surrounding property. Samples were obtained from the edge of the distribution structure (a location where concentrations would be expected to be highest), at the property boundary, and at the nearest residence. A multisorbent tube was used and a measured volume of air passed through the tube on site. The tube was then sealed and transported to Mann Testing Laboratories for gas chromatography/mass spectrometer analysis of volatile organics. The laboratory was instructed to analyse the tube at the distribution trench first and if any significant concentrations were detected, to proceed with analysis of other samples. Results indicated that inside the compound at the point of highest anticipated concentrations, levels were extremely low, barely above detections limits. A benzene reading of 0.59 ng/l was recorded. This reading is approximately 3 orders of magnitude (1000 times) lower than the MOE standard for this compound. Based on these results the other samples were not analysed.

6.0 WESA-MOE DETAILED CHEMICAL ANALYSIS

6.1 Water Chemistry Monitoring Program

Between July 27 and August 7, 1987, a thorough study of the treatment field and the status of the plume was conducted. WESA carried out the sampling program in conjunction with

Ministry of the Environment personnel from the Kingston District Office. The Mobile Trace Organic Laboratory of the Ministry's Laboratory Service Branch was situated on site during the evaluation to provide the necessary laboratory support for the volatile organic analyses. In addition, laboratory support for the analysis of other parameters was provided by the MOE Central Laboratory, the Kingston Laboratory, Queen's University Laboratory and Mann Testing Labs of Mississauga.

The purpose of this study was to field test the application of purge well and biological treatment technology for the remediation of contaminated aquifers. If successful, the remedial work would reduce the levels of organic compounds, in a seriously contaminated groundwater aquifer, to existing drinking water standards and demonstrate the effectiveness of overland flow/biological treatment. The organic compounds of particular concern in this situation were aromatic volatile organic compounds (such as benzene) and less volatile polynuclear aromatic hydrocarbons such as naphthalene and indene.

Water samples were collected from three sources to monitor the status of the contaminant plume and the performance of the treatment facility. These are: all private wells within the affected area; groundwater samples from the shallow overburden piezometers; and samples, comprising untreated groundwater and water from various distances along the treatment channels and field.

Within the treatment facility, the parameters of interest included conductivity, alkalinity, calcium, magnesium, sulfate, nitrate, nitrite, ammonia, phosphorus, COD, BOD, trace metals, polynuclear aromatic hydrocarbons, volatile hydrocarbons and phenols. In addition, flow cell analyses were carried out along the hay filled treatment channel BA. These measurements determined temperature, O_2 concentration, EH, and conductivity.

6.2 Sampling Methods

Samples for volatile organic analyses were collected without headspace in 100 ml glass bottles and sealed with Teflon septa. The collection procedure involved filling the bottles with the sample tubing inside so that sample/air contact was minimized. After 6 rinses with the solution being sampled, the bottles were allowed to overflow for several minutes. Finally, the sample tubing was slowly withdrawn leaving a bubble of water protruding from the bottle necks. The bottles were then quickly capped and stored in a cooler with ice.

Samples for extraction were collected in 1 litre amber glass bottles, and sealed with foil lined caps. The collection procedure involved filling the bottles with the sample tubing inside. After 6 rinses with the solution being sampled the bottles were allowed to fill to within a few milliliters of the top. The foil liners were washed (first with HPLC grade methanol and then with the solution being sampled) and placed over the bottle neck. Finally, the caps were tightened in place and the bottle placed in a cooler with ice and stored at a temperature of less than 4 degrees centigrade.

Samples collected for major cation and anion analysis were stored in polyethylene or glass 1 L bottles and were kept cool until their arrival at the laboratory. Samples collected for metals analysis were first filtered through a 0.45 um membrane and then acidified with nitric acid.

6.3 Flow Cell Measurements

A Canlab combination pH electrode was standardized with using buffered solutions with pH's of 4, 7 and 10 for field pH measurement. A platinum electrode was standardized in a ferrous/ferric solution (Light, 1972) for field EH measurement. Sampling tubes were connected to a peristaltic pump which was, in turn, connected to the flow cell. The cell contained the standardized pH, and EH probes as well as a conductivity/temperature probe. Pumping at each site was continued until all readings stabilized, which generally required 10 minutes once the flow cell was full. The readings were then recorded, the flow cell disassembled, the probes restandardized, and the system set up at a new location.

All tubing and filtering equipment was washed between samples by rinsing several times with distilled water, then with a 50% solution of nitric acid, followed by several more rinses with distilled water. In addition, the system was flushed with the solution to be sampled for 10 minutes prior to sample collection to prevent carry-over of dissolved material between sampling locations. In general the cation and anion samples were collected after the flow cell measurements were completed, to ensure representative samples.

6.4 WESA-MOE Results and Discussion

6.4.1 Private Wells

Many of the contaminated wells in Delta are completed in the bedrock, at depths between 13 and 40 metres. A few shallow dug wells were also contaminated, but these tend to be located near the source area.

Among the components of gasoline which constitute the greatest threat to health, benzene, an aromatic hydrocarbon, was found to be the one most consistently present in high concentration in groundwater from private wells. The highest concentrations of benzene were encountered at the homes located along the north side of Highway 42 southwest of the service station where the leak occurred. Most homes were much less severely affected, with benzene concentrations ranging between 10 and 200 ppb. This was the situation as it existed at the time the treatment field began operation.

Seven months after the purge well was switched on, 59 million litres (13 million gallons) of contaminated water had been pumped and all private wells within the affected area had concentrations of benzene below the World Health Organization drinking water guideline limit of 10 ppb (adopted by the MOE). In fact, none of the common aromatic constituents of gasoline were present above trace levels (Table 6). Only some of the odiferous, aliphatic compounds remained detectable.

6.4.2 Overburden / Bedrock Piezometers

In July 1987, seven months after the purge well was switched on, the contaminant concentrations in the overburden water remained between the non-detectable (<1 ppb background) and 1000 ppb. The highest concentrations were encountered between 100 and 200 metres downgradient from the source, with benzene present at 825 and 950 ppb at piezometers GD6 and GD5. Trace levels of hydrocarbons were detected at piezometer D1, 388 metres away from the source (Table 7a, 7b). These data indicate that the purge well currently in operation within the bedrock aquifer is not effective in cleaning up the overburden aquifer. It is likely that a second purge well will be required to decontaminate the overburden aquifer.

6.4.3 Treatment Field

The treatment field was sampled intensively in July, 1987, to examine the effectiveness of the treatment process more thoroughly (Table 8). Sampling points were established along the flow path in both the grass field (A) and the channels BA, BB, BC (Figure 2). In field A, sampling points were established by partially burying plastic drinking water cups in the field, so that the rims were at ground level. This created a series of small reservoirs for sampling purposes. Two sampling lines were established along the length of the grass field, each having 5 sampling points. Three points along each line were within 5 m of the sprinkler basin; the two remaining points along each line were located at the midpoint and the end of the field, respectively.

In each of the channels (Field B), sampling points were established by strapping 1/4 inch diameter polyethylene tubing to 1/2 inch diameter PVC stock. A filter mesh (#200) was strapped

Table 6

RESULTS OF DELTA HOME SAMPLING PROGRAM, SUMMER, 1987, RAW WATER
Sampling conducted by Water and Earth Science Associates
Analyses performed by MOE (Mobile Laboratory)

Blanks = not sampled or not analysed; 0 = not detected

System Delivery: ACF-P = Activated Carbon Filter - Parallel
System Delivery: ACF-P-WD = Activated Carbon Filter - Parallel - Water Delivery
System Delivery: ACF-S-WD = Activated Carbon Filter - Series - Water Delivery
System Delivery: Mon = Monitor

Lot	Name	Well Depth (m)	System	111TCEA (ug/L)	BENZ (ug/L)	TOL (ug/L)	TECEE (ug/L)	ETBENZ (ug/L)	o-XYL (ug/L)	m-XYL (ug/L)	CHCL3 (ug/L)	CCL4 (ug/L)	112TCEA (ug/L)	CLBENZ (ug/L)	CHBR3 (ug/L)	1122TCEA (ug/L)	14CL2BENZ (ug/L)	13CL2BENZ (ug/L)	12CL2BENZ (ug/L)	BRCL2CH TCEE (ug/L)	PHEN (ug/L)
13	Steary			0	0	0	0	0	0	0											0
14	Vollick	13.7		0	0	0	0	0	0	0											0
15	Pratt B.																				
16				0	0	0	0	0	0	0											0
17	Pratt I.		ACF-P	0	0	0	0	0	0	0											0
18	Halliday		ACF-P	0	3	0	0	0	0	0											0
19	Jacques	29.0	ACF-P-WD	0	0	0	0	0	0	0											0
20	Donald		ACF-S-WD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Price	9.1	ACF-P-WD																		0
22	Grant			0	0	0	0	0	0	0											0
24	Ayres			0	0	0	0	0	0	0											0
25	Phillips	16.8	ACF-WD	0	0	0	0	0	0	0											0
26	Connell	39.6	WD																		
27	Pratt Apts	24.4	ACF	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
28	Gray G.	9.7		0	0	0	0	0	0	0											0
29	French			0	0	0	0	0	0	0											0
30	Coon		ACF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Sly		Mon	0	0	2	0	0	5	0											
32	Breedyk	14.6	Mon	0	0	0	0	0	0	0											0
43	SCHOOL WR		ACF-3	0	0	0	0	0	0	0											0
43	SCHOOL BR		ACF-3																		
45	Laforty	13.7	ACF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	Atkin	3.0																			
47	Gray K.		ACF																		
48	Henderson		ACF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	Kitson	3.0		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	Wing	6.1	ACF	0	0	0	0	0	0	0											0
51	POST OFFICE	0.6	WD	0	0	0	0	0	0	0											0
52	Halliday	12.2		0	0	0	0	0	0	0											
53	UNITED CHURCH			0	0	0	0	0	0	0											
54	Stankiewiez	21.0		0	0	0	0	0	0	0											0
55	Russell H.	28.3		0	0	0	0	0	0	0											0
56	U.M.P.	30.5		0	0	0	0	0	0	0											0
57	Gravelle			0	0	0	0	0	0	0											0
60				0	0	0	0	0	0	0											
170	Gray	21.3																			
172	Russell L.			0	0	0	0	0	0	0											0
173	Schleede	15.2		0	0	0	0	0	0	0											0
174	RED & WHITE	25.0		0	0	0	0	0	0	0											0
175	LIQUOR STORE			0	0	0	0	0	0	0											0

Table 7a

RESULTS OF THE PIEZOMETER SAMPLING PROGRAM, DELTA, SUMMER, 1987 Overburden Piezometers
Sampling conducted by Water and Earth Science Associates
Analyses performed by MOE (Mobile Laboratory)
Blanks = no analysed or not sampled; 0 = not detected

Loc	Elev m.a.s.l.	Depth (m)	111TCEA (ug/L)	BENZ (ug/L)	TOL (ug/L)	TECEE (ug/L)	ETBENZ (ug/L)	o-XYL (ug/L)	m-XYL (ug/L)	CHCL3 (ug/L)	CCL4 (ug/L)	112TCEA (ug/L)	CLBENZ (ug/L)	CHBR3 (ug/L)	1122TCEA (ug/L)	14CL2BENZ (ug/L)	13CL2BENZ (ug/L)	12CL2BENZ (ug/L)	BRCL2CH TCEE (ug/L)	PHEN (ug/L)
GD1-1	89.85	7.62																		
GD1-2	90.76	6.71																		
GD1-3	92.59	4.88																		
GD1-4	94.42	3.05																		
GD2-1	84.47	12.09																		
GD2-2	85.97	10.59																		
GD2-3	87.47	9.09																		
GD2-4	88.97	7.59																		
GD2-5	90.47	6.09																		
GD3-1	84.32	12.02																		
GD3-2	85.82	10.52																		
GD3-3	87.82	8.52	0	116	168	0	221	23	164	0	0	0	0	0	0	0	0	0	0	
GD3-4	88.82	7.52																		
GD3-5	90.32	6.02	0	44	20	0	122	18	30											
GD4-1	83.84	11.42																		
GD4-2	84.84	10.42																		
GD5-1	83.13	12.48	0	950	0	0	0	0	0											
GD5-2	84.13	11.48																		
GD5-3	85.13	10.48																		
GD5-4	86.13	9.48																		
GD5-5	87.13	8.48																		
GD5-6	88.13	7.48																		
GD5-7	89.13	6.48																		
GD6-1	85.73	9.09	0	825	0	0	10	9	0											
GD6-2	86.73	8.09																		
GD7-1	86.15	8.86																		
GD7-2																				
GD8-1	91.06	4.5																		
GD9-1	91.31	5.03																		
GD10-1	79.45	16.38																		
GD10-2	80.45	15.38																		
GD10-3	81.45	14.38																		
GD10-4	82.45	13.38																		
GD10-5	83.45	12.38																		
GD10-6	84.45	11.38																		
GD10-7	85.45	10.38																		

Table 7b

RESULTS OF THE PIEZOMETER SAMPLING PROGRAM, DELTA, SUMMER, 1987   Bedrock Piezometers
Sampling conducted by Water and Earth Science Associates
Analyses performed by MOE (Mobile Laboratory)
Blanks = no analysed or not sampled; 0 = not detected

Loc	Elev m.a.s.l.	Depth (m)	111TCEA (ug/L)	BENZ (ug/L)	TOL (ug/L)	TECEE (ug/L)	ETBENZ (ug/L)	o-XYL (ug/L)	m-XYL (ug/L)	CHCL3 (ug/L)	CCL4 (ug/L)	112TCEA (ug/L)	CLBENZ (ug/L)	CHBR3 (ug/L)	1122TCEA (ug/L)	14CL2BENZ (ug/L)	13CL2BENZ (ug/L)	12CL2BENZ (ug/L)	BRCL2CH TCEE (ug/L)	PHEN (ug/L)
D1-1	62.91	30.48																		
D1-2	75.10	18.29	0	6	0	0	0	0	0											
D1-3	81.20	12.19																		
D2-1	66.45	30.48																		
D2-2	70.11	26.82																		
D2-3	75.59	21.34																		
D2-4	87.79	9.14																		
D2-5	92.36	4.57	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
D3-1	64.63	30.68																		
D3-2	70.93	24.38																		
D3-3	78.55	16.76																		
D3-4	86.17	9.14																		
C4-1	49.08	45.72																		
D4-2	52.74	42.06																		
D4-3	69.81	24.99																		
D4-4	86.27	8.53																		
D5-1	63.08	30.48	0	73	0	0	11	0	0											
D5-2	70.70	22.86	0	2	0	0	0	0	0											
D5-3	75.27	18.29																		
D5-4	79.84	13.72																		
D6-1	62.91	30.48																		
D6-2	67.48	25.91																		
D6-3	73.58	19.81																		
D6-4	84.25	9.14																		

Table 8 **RESULTS OF DELTA TREATMENT FIELD SAMPLING PROGRAM, SUMMER, 1987**
Sampling conducted by Water and Earth Science Associates
Analyses performed by MOE (inorganic chemistry at Kingston, trace metals at Toronto)
Blanks = not sampled or not analysed; 0 = below detection limit

Location	Dist. Source (m)	Depth (m)	TEMP C	COND Field (umhos)	COND Lab (umhos)	pH	Eh (mv)	O2 (ppm)	ALK CaCO3 (ppm)	HARD CaCO3 (ppm)	Ca (ppm)	Mg (ppm)	SO4 (ppm)	NO3 (ppm)	NO2 (ppm)	NH3 (ppm)	DRP (ppm)	COD (ppm)	BOD (ppm)	Fe BACT. P=present O=absent
A Tap	0.0	54.25			980				323	384	99.0	33.4	41	0.09	0.012	0.11	0.008	0	0.5	0
A TRENCH	0.0	0			965				322	360	90.9	32.3	40	0.07	0.01	0.08	0	0	0.3	0
A1	0.0	0																		
A1-1	0.2	0																		
A1-2	3.0	0																		
A1-3	6.0	0																		
A1-4	23.0	0																		
A1-5	45.0	0																		
A1-6	59.0	0																		
A2-1	0.2	0			975				319	361	91.0	32.4	40	0.09	0.008	0.08	0	0	0.5	P
A2-2	3.5	0			960				337	373	95.3	32.8	40	0.04	0.004	0	0	10	0.7	^
A2-3	7.0	0			960				335	387	98.7	34.0	41	0	0.002	0.01	0.010	10	0.7	0
A2-4	22.0	0			935				316	338	85.0	30.7	39	0	0.006	0.03	0.002	10	0.4	0
A2-5	45.0	0			940				317	319	82.4	27.6	40	0	0.002	0.03	0.012	0	0.5	0
A2-6	61.0	0			915				297	352	78.9	37.8	39	0	0.002	0.03	0	0	0.4	0
B Tap	0.0	54.25	13		975	8.5	69	1.8	340	368	91.3	34.1	39	0.07	0.012	0.11	0	12	0.6	0
B TRENCH	0.0	0.00																		
BA-1	2.0	0.05			962				330	360	88.2	33.9	40	0.09	0.008	0.025	0.032	5	0.25	0
BA-2	2.0	0.05			970				326	344	85.6	31.6	42	0.09	0.008	0.03	0	0	0.45	P
BA-3	5.0	0.01	22	270	960	7.7	329	8.3	314	359	88.7	33.5	41	0.05	0.006	0.02	0	0	0.4	P
BA-4	14.0	0.03	24.5	398	960	7.9	337	8.7	318	362	90.6	33.0	40	0.03	0.006	0.02	0	24	0.7	0
BA-5	32.0	0.01	26	498	935	7.7	394	9.8	293	335	79.3	33.4	41	0.06	0.004	0.03	0	30	0.9	P
BA-6	66.0	0.08	28	650	915	7.8	347	8.4	292	333	79.4	32.8	42	0	0.002	0.03	0	12	0.9	P
BA-7	144.0	0.00	26	700	940	8.2	229	5.4	305	354	86.3	33.6	43	0.02	0.002	0.06	0	20	1.3	0
BB-1	2.0	0.05																		
BB-2	2.0	0.08																		
BB-3	4.0	0.11																		
BB-4	9.0	0.15																		
BB-5	30.0	0.06																		
BB-6	81.0	0.07																		
BB-7	132.0	0.00																		
BC-1	2.0	0.11																		
BC-2	2.0	0.04																		
BC-3	5.0	0.03																		
BC-4	12.0	0.14																		
BC-5	26.0	0.09																		
BC-6	109.0	0.05																		
BC-7	164.0	0.00																		
Cement Notch Exit		0			940				304	336	81.8	32.1	32	5.26	0.042	0	0.004	33	7.6	P
FOUNDRY Upstream		0			401				210	220	45.4	26.0	4	0.11	0.01	0.03	0.034	35	0.7	P
CREEK Downstream		0			431				216	227	47.7	26.2	6	0.11	0.01	0.03	0.110	30	0.7	P

Table 8

RESULTS OF DELTA TREATMENT FIELD SAMPLING PROGRAM, SUMMER, 1987
Sampling conducted by Water and Earth Science Associates
Analyses performed by MOE (inorganic chemistry at Kingston, trace metals at Toronto)
Blanks = not sampled or not analysed; 0 = below detection limit

Location	Dist. Source (m)	Depth (m)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Al (ppm)	Ba (ppm)	Be (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Mo (ppm)	Se (ppm)	St (ppm)	Ti (ppm)	Vd (ppm)
A Tap	0.0	54.25	1.300	0.170	<0.001	0.002	<0.003	0.022		0.041	0.33	<0.001	<0.0003	<0.001	<0.001	<0.001		3.6	<0.003	<0.001
A TRENCH	0.0	0	0.022	0.150	<0.001	<0.002	<0.003	0.039		0.041	0.31	<0.001	<0.0003	0.002	<0.001	<0.001		3.6	<0.003	<0.001
A1	0.0	0																		
A1-1	0.2	0																		
A1-2	3.0	0																		
A1-3	6.0	0																		
A1-4	23.0	0																		
A1-5	45.0	0																		
A1-6	59.0	0																		
A2-1	0.2	0	0.210	0.150	<0.001	<0.002	<0.003	0.020		0.040	0.33	<0.001	<0.0003	<0.001	<0.001	<0.001		3.6	<0.003	<0.001
A2-2	3.5	0	0.006	0.037	<0.001	<0.002	<0.003	0.020		0.041	0.32	<0.001	<0.0003	0.001	<0.001	<0.001		3.6	<0.003	<0.001
A2-3	7.0	0	0.001	0.006	<0.001	<0.002	<0.003	0.020		0.069	0.32	<0.001	<0.0003	0.001	<0.001	<0.001		3.6	<0.003	<0.001
A2-4	22.0	0	0.010	0.002	0.001	<0.002	<0.003	0.030		0.052	0.29	<0.001	<0.0003	0.001	<0.001	<0.001		3.5	<0.003	<0.001
A2-5	45.0	0	0.014	0.003	<0.001	<0.002	<0.003	0.030		0.061	0.27	<0.001	<0.0003	0.001	<0.001	<0.001		3.4	<0.003	<0.001
A2-6	61.0	0	0.002	0.005	<0.001	<0.002	<0.003	0.026		0.048	0.27	<0.001	<0.0003	0.001	<0.001	<0.001		3.4	<0.003	<0.001
B Tap	0.0	54.25	0.070	0.011	<0.001	<0.002	<0.003	0.002		<0.004	0.021	<0.001	<0.0003	<0.001	<0.001	<0.001		0.27	<0.003	<0.001
B TRENCH	0.0	0																		
BA-1	2.0	0.05	0.043	0.098	<0.001	<0.002	<0.003	0.021		0.042	0.32	<0.001	<0.0003	0.001	<0.001	<0.001		3.7	<0.003	<0.001
BA-2	2.0	0.05	0.042	0.052	<0.001	<0.002	<0.003	0.060		0.047	0.32	<0.001	<0.0003	0.001	<0.001	<0.001		3.7	<0.003	<0.001
BA-3	5.0	0.01	0.130	0.048	0.002	0.002	<0.003	0.064		0.540	0.32	<0.001	<0.0003	<0.001	<0.001	<0.001		3.7	<0.003	<0.001
BA-4	14.0	0.03	0.220	0.036	<0.001	0.003	<0.003	0.023		0.043	0.31	<0.001	<0.0003	<0.001	<0.001	<0.001		3.6	<0.003	<0.001
BA-5	32.0	0.01	0.016	0.018	<0.001	<0.002	<0.003	0.019		0.041	0.31	<0.001	<0.0003	0.001	<0.001	<0.001		3.6	<0.003	<0.001
BA-6	66.0	0.08	0.014	0.023	<0.001	0.002	<0.003	0.060		0.042	0.31	<0.001	<0.0003	0.001	<0.001	<0.001		3.6	<0.003	<0.001
BA-7	144.0	0.00	0.018	0.012	<0.001	<0.002	<0.003	0.030		0.051	0.31	<0.001	<0.0003	0.001	<0.001	<0.001		3.6	<0.003	<0.001
BB-1	2.0	0.05																		
BB-2	2.0	0.08																		
BB-3	4.0	0.11																		
BB-4	9.0	0.15																		
BB-5	30.0	0.06																		
BB-6	81.0	0.07																		
BB-7	152.0	0.00																		
BC-1	2.0	0.11																		
BC-2	2.0	0.04																		
BC-3	5.0	0.03																		
BC-4	12.0	0.14																		
BC-5	26.0	0.09																		
BC-6	109.0	0.05																		
BC-7	164.0	0.00																		
Cement Notch Exit 1		0	0.160	0.210	0.001	<0.003	<0.006	0.040		0.054	0.300	<0.001	<0.0005	<0.002	<0.001	<0.001		3.9	<0.005	<0.001
Cement Notch Exit 2		0	1.200		0.002	0.002	<0.003	0.450	<0.001	0.600	0.094		<0.0003	<0.001	0.001		<0.001			
FOUNDRY Upstream 1		0	0.053	0.034	<0.003	<0.015	0.030	0.006		0.057	0.350	<0.005	<0.003	<0.010	<0.005	<0.003		4.5	<0.025	<0.004
Upstream 2		0	0.270	0.083	0.003	<0.007	<0.003	0.040		0.057	0.065	<0.001	<0.003	<0.001	<0.001	<0.001		0.3	<0.003	0.001
[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted] [redacted] [redacted] [redacted]

Table 8: **RESULTS OF VOLATILE ORGANIC SAMPLING PROGRAM FOR THE DELTA TREATMENT FIELD, SUMMER, 1987**
Sampling performed by Water and Earth Science Associates
Analyses performed by MOE mobile laboratory
Blanks = not sampled or not analysed; 0 = not detected; Tr = Trace

Location	Dist. Source (m)	Depth (m)	111TCEA (ug/L)	BENZ (ug/L)	TOL (ug/L)	TECEE (ug/L)	ETBENZ (ug/L)	o-XYL (ug/L)	m-XYL (ug/L)	CHCL3 (ug/L)	CCL4 (ug/L)	112TCEA (ug/L)	CLBENZ (ug/L)	CHBR3 (ug/L)	1122TCEA (ug/L)	14CL2BENZ (ug/L)	13CL2BENZ (ug/L)	12CL2BENZ (ug/L)	BRCL2CH TCEE (ug/L)	PHEN (ug/L)	Napthalene	% Recovery D-10 Anthracene
A Tap	0.0	54.25	0	81.5	2	0	51	0	9	0	0	0	0	0	0	0	0	0	0	0		
A TRENCH	0.0	0.00	0	21	1	0	16	0	3	0	0	0	0	0	0	0	0	0	11	0		
A1	0.0	0.00																				
A1-1	0.2	0.00	0	20.5	2	0	12.5	0	3	0	0	0	0	0	0	0	0	0	0	0		
A1-2	3.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
A1-3	6.0	0.00	0	0	0	0	0	0	0											0		
A1-4	23.0	0.00	0	0	0	0	0	0	0											0		
A1-5	45.0	0.00	0	0	0	0	0	0	0											0		
A1-6	59.0	0.00	0	0	0	0	0	0	0											0		
A2-1	0.2	0.00	0	3	0	0	3	0	0											0	Tr	84
A2-2	3.5	0.00	0	0	0	0	0	0	0											0		
A2-3	7.0	0.00	0	0	0	0	0	0	0											0		
A2-4	22.0	0.00	0	0	0	0	0	0	0											0		
A2-5	45.0	0.00	0	0	0	0	0	0	0											0		
A2-6	61.0	0.00	0	0	0	0	0	0	0											0		
B Tap	0.0	54.25	0	84	2	0	51.5	0	10	0	0	0	0	0	0	0	0	0	10	0		
B TRENCH	0.0	0.00																				
BA-1	2.0	0.05	0	2	0	0	0	0	0											0	0	92
BA-2	2.0	0.05	0	2	0	0	0	0	0											0		
BA-3	5.0	0.01	0	2	0	0	0	0	0											0		
BA-4	14.0	0.03	0	0	0	0	0	0	0											0	0	95
BA-5	32.0	0.01	0	0	0	0	0	0	0											0		
BA-6	66.0	0.08	0	0	0	0	0	0	0											0		
BA-7	144.0	0.00	0	0	0	0	0	0	0											0		
BB-1	2.0	0.05	0	8.5	0	0	5.5	0	2	0	0	0	0	0	0	0	0	0	0	0		
BB-2	2.0	0.08	0	4.5	0	0	3	0	2											0		
BB-3	4.0	0.11	0	3	0	0	0	0	0											0		
BB-4	9.0	0.15	0	2	0	0	0	0	0											0		
BB-5	30.0	0.06	0	0	0	0	0	0	0											0		
BB-6	81.0	0.07	0	0	0	0	0	0	0											0		
BB-7	152.0	0.00	0	0	0	0	0	0	0											0		
BC-1	2.0	0.11	0	4	0	0	3	0	2											0		
BC-2	2.0	0.04	0	16	0	0	7	0	3											0		
BC-3	5.0	0.03	0	2	0	0	0	0	0											0		
BC-4	12.0	0.14	0	2	0	0	0	0	0											0		
BC-5	26.0	0.09	0	2	0	0	0	0	0											0		
BC-6	109.0	0.05	0	0	0	0	0	0	0											0		
BC-7	164.0	0.00	0	0	0	0	0	0	0											0		
Cement Notch Exit		0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

NOTE Sample A2-1 for napthalene lost by laboratory to the end of the polyethylene tubes to prevent sediment from being drawn in during sampling. Six of these sampling points were placed along the lengths of each treatment channel (Figure 2). Two points were situated near the sprinkler basin, in each case. The remaining four were situated with increasing spacing along each channel length. In addition, samples were collected at the exit of each channel.

6.4.4 Inorganic Chemistry

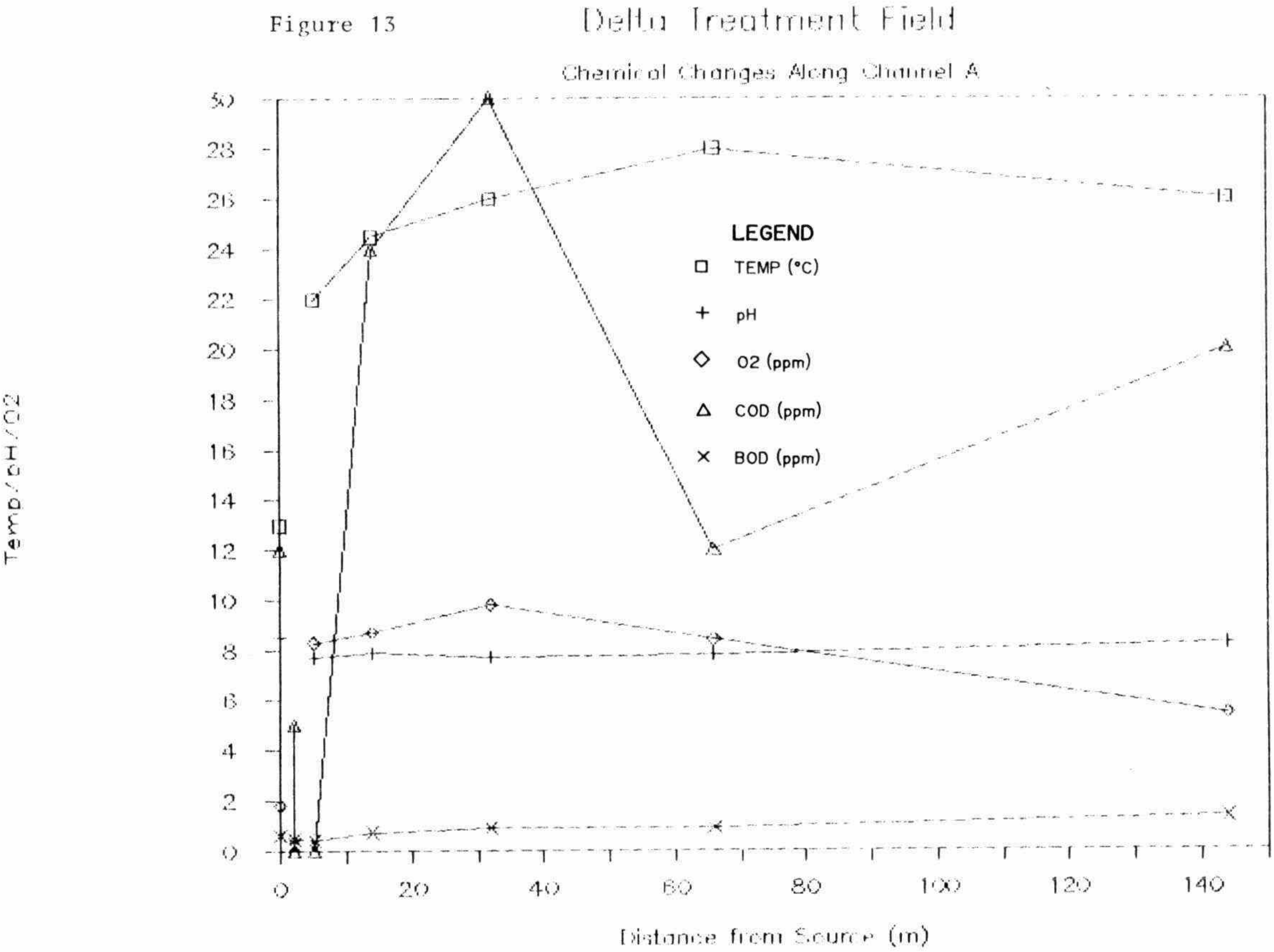
Along the length of the grass field, COD and BOD were found to be relatively constant (10 and 0.6 ppm, respectively). However, some trends were noted in data from the treatment channels. Along channel BA (hay filled), the COD was observed to rise sharply from 5 to 24 ppm 14 m from the source, and BOD rose gradually from 0.25 ppm at the source, to 1.3 ppm at the end of the channel (Table 8, Figure 13). These data indicate that organic matter, from the hay and soil lining the channel, is being dissolved.

Flow cell measurements gathered along channel BA indicate that the most notable changes to the water chemistry occur during the sprinkler phase of treatment. Dissolved oxygen concentrations increase sharply from <2 ppm at source to ~9 ppm at the base of the rip rap. A corresponding increase in the EH was also observed (rise from 69 mv to >300 mv). The water temperature was observed to rise from 13 C at the source to 22 C after the sprinklers.

In the channel, dissolved oxygen and EH were found to increase marginally up to 30 m from the source. Beyond this distance, both parameters were observed to decrease: at the discharge point from channel A, oxygen was present at a concentration of 5.4 ppm, EH was found to be 229 mv (Figures 13, 14). A similar trend was observed in the temperature measurements. A maximum temperature of 28 C was reached at a distance of about 66 m from the source. Beyond this point, temperature dropped slightly to 26 C at the discharge point. The temperature changes are probably the result of shadows cast across the lower end of the treatment channel on the day of the measurements. The changing oxygen concentration and EH may be directly due to the increasing BOD along the channel length.

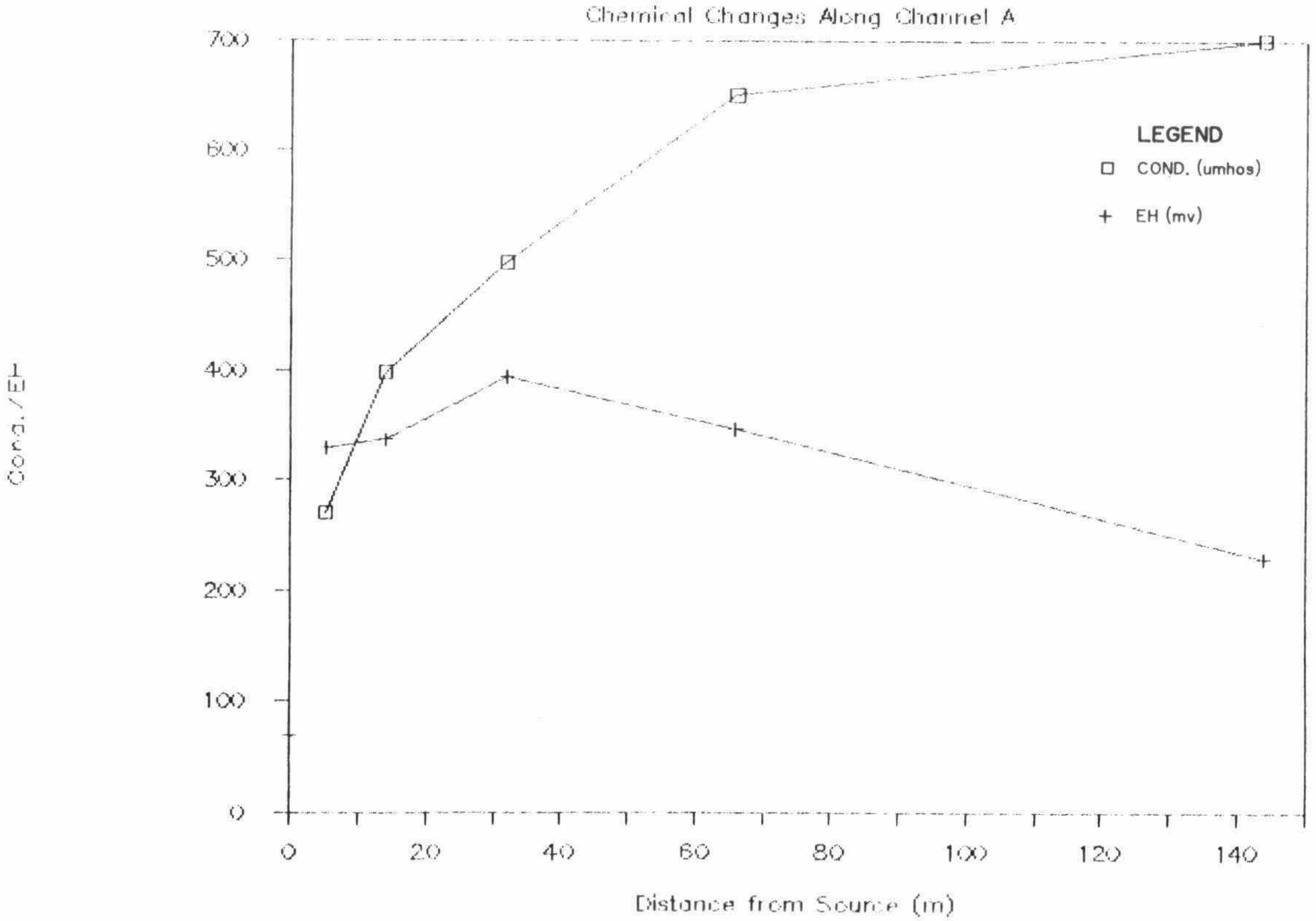
The only parameter which showed a systematic increase along the entire length of the channel was conductivity (as measured in the flow cell). Near the source, the conductance was measured at 270 umhos, while at the discharge point it found to be 700 umhos (Figure 14). This rise is most likely due to dissolved organic matter, since the major inorganic ionic species show no appreciable change in concentration but the COD increases significant along the channel length. Conductivity measurements conducted at the MOE laboratory (Kingston) do not reflect a

Figure 13



CHANGES IN CHEMICAL PARAMETERS ALONG TREATMENT CHANNEL BA

Figure 14 Delta Treatment Field



CHANGES IN CHEMICAL PARAMETERS ALONG TREATMENT CHANNEL BA similar trend. All the laboratory values are >900 umhos. The reason for this discrepancy has not been identified at this point in time.

In general, there are no significant changes to the concentrations of the major ionic species in the water as it flows across the grass field or through the treatment channels. Hardness is between 330 and 390 ppm ($CaCO_3$), total nitrogen does not exceed 0.15 ppm, alkalinity was measured to be between 240 and 360 ppm ($CaCO_3$), sulfate is present between 39 and 43 ppm, and phosphorus is only detectable in trace quantities. Only iron concentrations have been shown to change during treatment. At source, levels are about 2 ppm; at discharge the concentration is <0.05 ppm. Most of the iron removal seems to occur near the rip rap, based on the severe staining on the cement basin and the gravel.

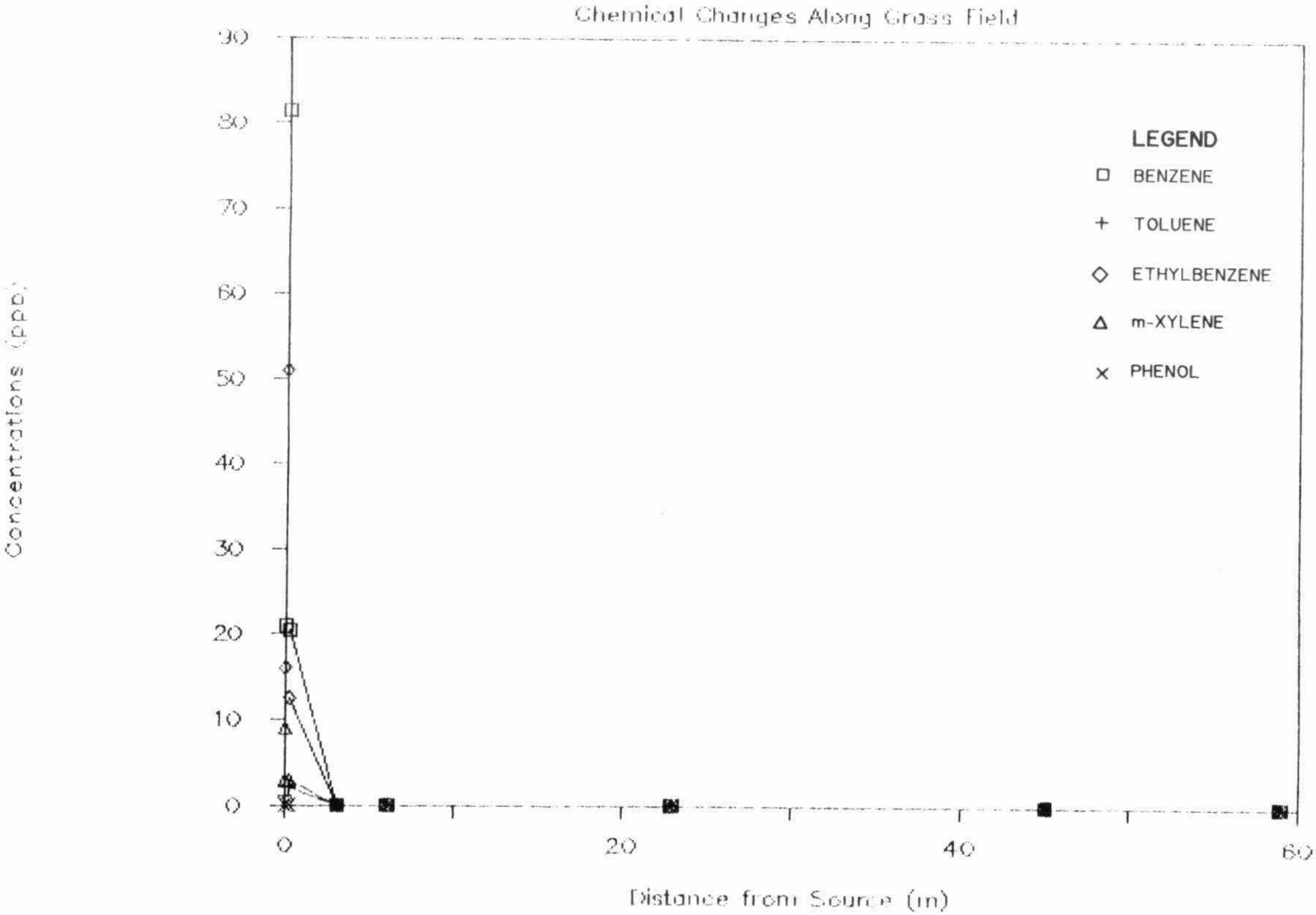
6.4.5 Organic Chemistry

The organic contaminants considered in this study are listed in Appendix C. The concentrations of these contaminants at various distances along the grass field and the treatment channels are also presented in Table 8 and shown graphically in Figures 15 and 16. These data demonstrate that the attenuation of the organic contaminants occurs almost entirely within the first few metres of the rip rap.

Contaminant concentrations in the water filling the cement basins, and at the base of the rip rap in Field A (grass field) are about one quarter of those measured in the untreated water (benzene was measured at 20 ppb in the trench and 80 ppb at source; ethylbenzene was measured at 16 ppb in the trench and 51 ppb at source; xylene was measured at 3 ppb in the trench and 9 ppb at source). These data indicate that the sprinkler aeration system is responsible for approximately 75% removal of volatile contaminants. Three metres away from the rip rap levels of all contaminants except benzene are below analytical detection limits (1 ppb). Benzene is present in trace amounts for only a few metres beyond that (Figure 15).

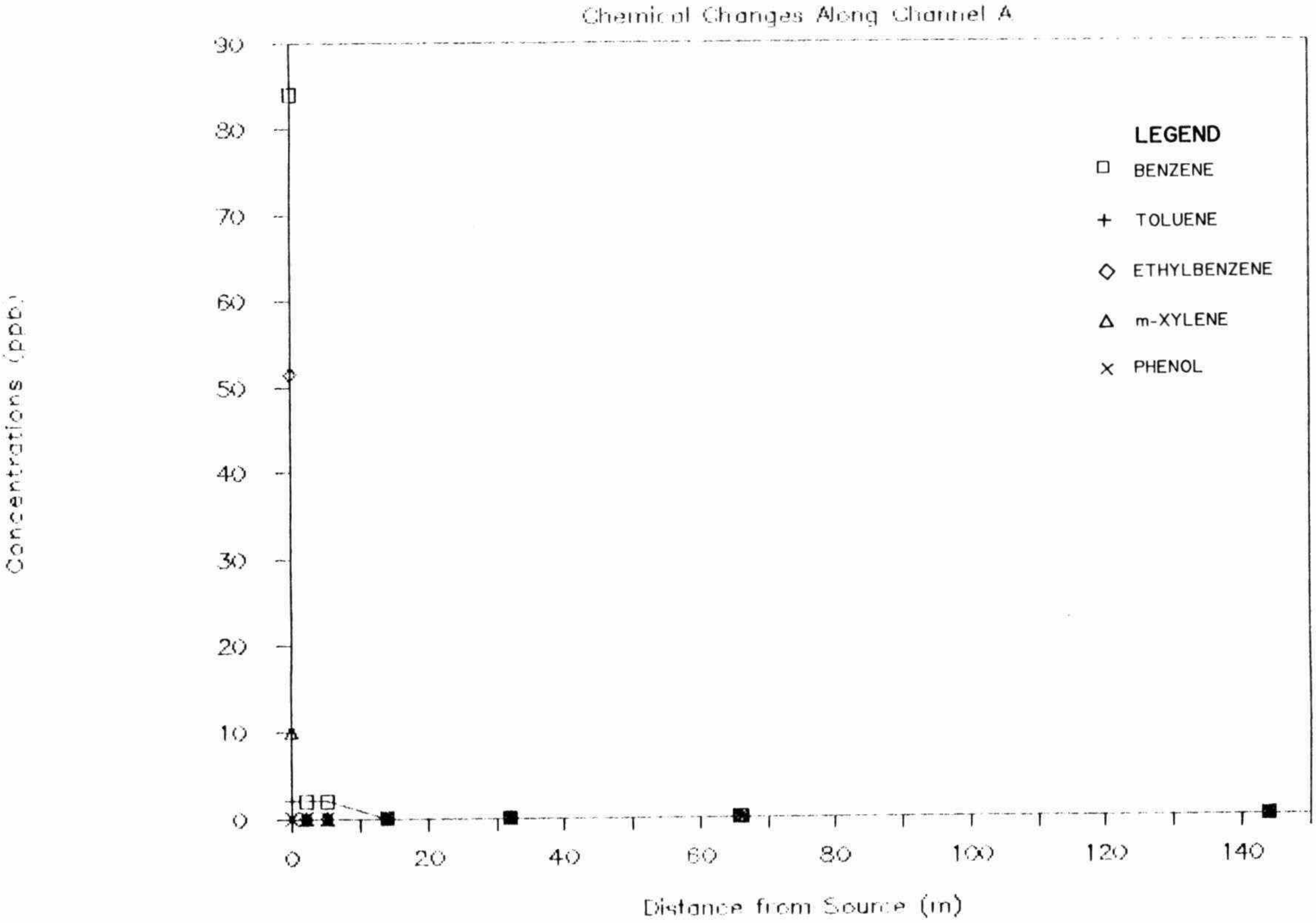
Low levels of bromodichloromethane and trichloroethylene were reported in the untreated water at the treatment site (A trench 11 ppb and B Tap 10 ppb). These analyses were carried out by GC only, with no verification by mass spectrometry. Discussions with laboratory personnel indicate that such results may be due to impurities introduced by labware. These contaminants are not considered to be indicative of the contamination in the groundwater, since previous priority pollutant scans have not revealed the presence of these compounds.

Figure 15 Delta Treatment Field



CONTAMINANT CONCENTRATIONS ALONG THE GRASS TREATMENT FIELD (A)

Figure 16 Delta Treatment Field



CONTAMINANT CONCENTRATIONS ALONG TREATMENT CHANNEL BA

7.0 CONCLUSIONS

The rehabilitation of aquifers which have been contaminated with organic compounds is a new and important science in Ontario. Many of the hydrogeology, geochemistry and engineering principles which now permit remediation of groundwater supplies have only been developed within the last five years. However, much of the existing technology was developed for other types of wastewater treatment, and is extremely expensive or technically unsound when applied to groundwater rehabilitation problems.

The methods tested in this report should be applicable to a wide range of groundwater rehabilitation problems associated with spills, landfill operations and remedial undertakings. However, the research to date is solely applicable to gas spill problems.

The following conclusions may be drawn from the work conducted in this study:

1) Overland biological treatment of groundwater is an effective method for cleaning up gasoline contaminated groundwater (dissolved phase), and for removing most of the iron associated with the hydrocarbon plume.

2) Throughout 1987, the quality of the discharge water remained high and no significant (contaminant related) stress was observed in the vegetation. Thus, preliminary results indicate the system is suitable for long term treatment.

3) The treatment facility at Delta could be scaled down considerably and maintain its effectiveness in cleaning up groundwater contaminated with gasoline. Most of the removal of hydrocarbon and iron appears to be taking place in the first few metres.

4) Within a seven month time period all wells within a few hundred metres of the purge well (and completed in bedrock) have experienced major improvements in water quality. None of the formerly contaminated private wells contain volatile aromatic organics at more than trace levels (1-4 ppb). All values are below recognized health drinking water guidelines (i.e. World Health Organization). Some odour persists in water from the homes which were most severely affected in the past; however, this problem is likely the result of low levels of aliphatic hydrocarbons for which no drinking water limit has been set.

5) No significant differences were observed in the attenuating properties of hay, frog-bit, or wetland grasses.

6) Approximately 75% of volatile contaminants may be removed from water through the use of a sprinkler system (for contaminant levels between 50 and 100 ppb).

7) The purge well is effectively cleaning up the bedrock aquifer, but not the overburden aquifer. It is likely that a second purge well, completed in the overburden, will be necessary before the site can be restored.

8) The average drawdown in the purge well at 75 IGPM (5.7 L/sec.) is about 5 metres (16.4 ft.) and is not expected to increase significantly or adversely interfere with neighbouring water supplies in the future.

9) No air quality threat or health hazard is present in the vicinity of the treatment area.

10) The rehabilitation of groundwater by purge well and biological treatment is effective at a fraction of the cost of conventional methods.

8.0 REFERENCES

1) WESA
1986: "Remediation of a Water Supply Aquifer Contaminated with dissolved Phase Gasoline. Delta, Ontario. An Engineering Report"

2) WESA
1987: "Low Cost Treatment Technology for Gasoline Contaminated Groundwater, Delta, Ontario, Canada"

3) Light, T.S.
1972: "Standard Solution for Redox Potential Measurements", Anal. Chem., V.44, No. 6, pg. 1038-1039.

APPENDIX A

MINISTRY OF ENVIRONMENT CERTIFICATE OF APPROVAL

NOV 7 198

Ministry of the Environment
Ministère de l'Environnement
Ontario

Certificate of Approval (Sewage)
Certificat d'autorisation (eaux usée

Number / *Numéro* 4-069-86-006

Whereas / *Attendu que* A.E. Williams and Co. Ltd.

of / *d* Toronto, Ontario

has applied in accordance with Section 24 of the Ontario Water Resources Act for approval of:
a fait, conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

A wastewater treatment system for the treatment of contaminated groundwate to be located west of Main Street, south of Foundry Street and along the east side of Cowans Creek (Foundry Creek) in the Township of Bastard and South Burgess (Delta), consisting of a purge well equipped with a submersible well pump rated at 6.05 L/sec at a TDH of 75 m, pump discharge header with spray nozzles located in two (2) distribution channels serving two (2) treatment fields, treatment field "A" with an area of approximatel 0.3 ha for the purposes of overland flow treatment and with various varieties of grasses grown on the field and treatment field "B" with an are of approximately 0.3 ha for the purposes of channel flow treatment consisting of three (3) sinusoidal aligned flow channels with rough-hewn timber overflow weirs varying in length between 150 m to 200 m with Channe No. 1 being planted with tall robust and/or narrow-leaved vegetation, Channel No. 2 being planted with broad-leaved vegetation and Channel No. 3 being planted with floating-rooted or submerged vegetation; a cattail marsh to be located at the end of the process adjacent to and discharging to Cowans Creek and planted with two (2) species of local cattails, all including associated equipment and appurtenances, all in accordance with th plans prepared by Kostuch Engineering Ltd., Consulting Engineers and the engineering report and equipment specifications submitted by Water and Earth Science Associates Ltd., at a total estimated cost, including engineering and contingencies, of ONE HUNDRED TWENTY FOUR THOUSAND TWO HUNDRED FIFTY DOLLARS ($124,250.00), subject to the following special terms and conditions which are considered necessary by the undersigned.

SPECIAL TERMS AND CONDITIONS

1. Performance Monitoring

   i) A monitoring program approved by the District Officer of the Kingston District Office of the Ministry of the Environment shall be implemented during the initial stages of operation of the facility to determine if diurnal variations exist in either the raw purge well discharge or the effluent to Cowans Creek. Upon demonstration that no significant diurnal variation exist and upon

....2

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

Le présent document *certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this 4th day of November, 1986
DATÉ À TORONTO ce *jour d*

Whereas / *Attendu que*

d

applied in accordance with Section 24 of the Ontario Water Resources Act for approval of:
fait, conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

SPECIAL TERMS AND CONDITIONS (Cont'd)

approval of the District Officer of the Kingston District Office of the Ministry of the Environment, an instantaneous weekly sample shall be sufficient for monitoring purposes.

ii) Each instantaneous weekly sample shall be analyzed for benzene, toluene, ethylbenzene, xylene, total phenol and iron. Additionally, the influent and effluent shall be analyzed on a monthly basis for trimethylbenzene, naphthalene and total polynuclear aromatic hydrocarbons (PAH's). The analytical results of all samples collected shall be reported to the operating authority within ten working days of the collection of the samples.

iii) Effluent flow rates shall be monitored such that daily discharge volumes can be readily and accurately calculated.

iv) The maximum allowable concentrations of effluent parameters at the outfall of the artifical marsh are as follows:

Parameter	Allowable Maximum Concentrations	
Benzene	25	ug/L
Toluene	60	ug/L
Ethylbenzene	60	ug/L
Xylene	50	ug/L
Trimethylbenzene	50	ug/L
Napthalene	60	ug/L
Total PAH	0.04	ug/L
Total Phenol	300	ug/L

v) The Abatement Section, Kingston District, Ministry of the Environment shall be notified immediately in the event any analysis of effluent discharge at the outfall of the artificial marsh exceeds the allowable maximum discharge criteria.

....3

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

Le présent document *certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this 4th day of November, 1986
DATÉ À TORONTO ce *jour d*

Whereas / *Attendu que*

has applied in accordance with Section 24 of the Ontario Water Resources Act for approval of:
a fait, conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

SPECIAL TERMS AND CONDITIONS (Cont'd)

vi) In the event that any analysis of effluent discharge at the outfall of the artificial marsh for the parameters of benzene, toluene, ethylbenzene, xylene, trimethylbenzene, naphthalene, and total PAH exceeds the allowable maximum discharge concentrations, an intensive monitoring program of the parameter(s) of exceedance shall be undertaken. The intensive monitoring program shall consist of, at a minimum, five (5) consecutive daily samples of the effluent discharge at the outfall of the artificial marsh. These samples shall be analyzed for the parameter(s) of exceedance and the arithmetic mean calculated. Non-compliance will be deemed to have occurred should the calculated arithmetic mean exceed the maximum allowable concentration. In the event non-compliance occurs, discharge to Cowans Creek shall be discontinued until appropriate process changes are made or an alternative treatment process is implemented.

vii) Notwithstanding any other condition of the Certificate, the discharge of contaminants to the environment during startup periods with the concurrence of the Ministry of the Environment may exceed maximum discharge criteria provided all reasonable steps are taken to minimize non-compliance with this Certificate of Approval. Under no circumstances during startup periods, shall discharge to Cowans Creek continue for longer than six weeks at contaminant levels exceeding the allowable maximum discharge criteria. The Abatement Section, Kingston District, Ministry of the Environment shall be notified immediately in the event allowable maximum discharge criteria are exceeded during startup periods.

2. Reporting

i) Monthly reports containing analytical results and flow weighted monthly average concentrations shall be submitted for the initial six month period of operation of the treatment facility. Monthly

....4

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

Le présent document *certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this 4th day of November, 1986
DATÉ À TORONTO ce 4th *jour d* November, 1986

Certificate of Approval (Sewage)
Certificat d'autorisation (eaux usées)

Number / *Numéro* 4-069-86-006
(Continued)

Whereas / *Attendu que*

has applied in accordance with Section 24 of the Ontario Water Resources Act for approval of:
a fait conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

SPECIAL TERMS AND CONDITIONS (Cont'd)

reports shall be submitted to the Abatement Section, Kingston District, Ministry of the Environment. Monthly reports shall report all data obtained during the month of concern for the performance monitoring program and remediation monitoring program and shall be submitted to the Ministry prior to the end of the following month. Requirements for monthly reporting shall be reviewed by the Ministry at the end of the initial six month operation period.

ii) Quarterly reports shall be submitted to the Abatement Section, Kingston District, Ministry of the Environment at three month intervals. The first report shall cover the period of October, November and December 1986. Quarterly reports shall be submitted to the Ministry prior to the end of the month following the reporting period. The quarterly reports shall contain, but not limited to, the following:

a) a summary and interpretation of all analytical data collected relative to, first, the purge well effluent treatment facility, and second, the remediation of groundwater contamination of the local aquifer during the period being reported.

b) a tabulation and description of all calibrations, maintenance, malfunction and unusual events which occurred during the period being reported.

iii) An annual performance report shall be submitted to the Abatement Section, Kingston District, Ministry of the Environment by September 30, 1987 and every September 30 thereafter while the facility is in operation. The annual performance report shall include, but not limited to, a summary of the four preceding quarterly reports including a detailed overview of the success/adequacy of the treatment facility and remediation of the

....5

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

***Le présent document** certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this 4th day of November, 1986
DATÉ À TORONTO ce *jour d*

Whereas / *Attendu que*

of / *d*

has applied in accordance with Section 24 of the Ontario Water Resources Act for approval of
a fait, conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

SPECIAL TERMS AND CONDITIONS (Cont'd)

groundwater contamination of the local groundwater aquifer, and a detailed interpretation of the effluent discharge concentration data.

iv) Following the initial six month period of operation of the treatment facility, the performance of the treatment facility shall be evaluated by the Ministry regarding future required sampling and reporting frequencies. The decision shall be forwarded by letter to the owner/operator of the facility and shall form part of the requirements of this Certificate of Approval.

v) All reports shall be signed by an officer of the company or the company's designated representative.

3. Analyses of all samples must employ analytical methods contained in the current publication of "Standard Methods for the Examination of Water and Wastewater" prepared and published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation.

4. Results of parameters measured, in addition to the minimum specified, or measured at frequencies in excess of the minimum requirements specified by this Certificate of Approval, shall be reported to the Ministry of the Environment.

5. Periodic calibration and maintenance procedures shall be carried out on all monitoring and analytical instrumentation to ensure accuracy of measurements.

6. A record of all calibrations, maintenance, malfunctions and unusual events pertaining to the purge well treatment process shall be maintained for inspection upon request at reasonable times by the Ministry. The record shall indicate the date, time and place of the

....6

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

Le présent document *certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this / *DATÉ À TORONTO ce* 4th day of / *jour d* November, 1986

Whereas / *Attendu que*

of / *d*

has applied in accordance with Section 24 of the Ontario Water Resources Act for approval of:
a fait conformément à l'article 24 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

SPECIAL TERMS AND CONDITIONS (Cont'd)

calibration, maintenance or unusual event and the name of the person who recorded the information.

7. Any and all unintentional upsets which result in a discharge of contaminants to the environment exceeding allowable maximum discharge criteria must be reported to the Abatement Section, Kingston District, Ministry of the Environment.

NOTE: "Upset" means an exceptional incident in which there is unintentional and temporary non-compliance with the Certificate of Approval because of factors beyond reasonable control. Factors within reasonable control include operational error, improperly designed facility, inadequate facilities, lack of preventative maintenance and careless operation causing non-compliance with this Certificate of Approval.

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 24 of the Ontario Water Resources Act.

Le présent document *certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 24 de la loi sur les ressources en eau de l'Ontario.*

DATED AT TORONTO this 4th day of November, 1986
DATÉ À TORONTO ce *jour d*

of the
Environment
Ontario

NOTICE

TO: A.E. Williams and Co. Ltd.
1000 Yonge Street
Toronto, Ontario

You are hereby notified that a Conditional Certificate of Approval No. 4-069-86-006 has been issued to you subject to the conditions outlined therein.

The reasons for the imposition of these conditions are as follows:

1. Due to the experimental nature of the proposal, an effective and intensive monitoring program, to monitor the performance of the system, is required in order to determine if the facility is capable of meeting the effluent quality requirements. Also, should the effluent be determined to exceed the maximum allowable concentrations, corrective action can be initiated.

   Therefore the reason for Condition No. 1 is to ensure that a satisfactory performance monitoring program is implemented.

2. In addition to a satisfactory performance monitoring program, an efficient reporting system must also be implemented to ensure that the Ministry is kept informed of the performance of the quality and the details of its operation.

   Therefore the reason for Condition No. 2 is to ensure that a suitable reporting system is in place to keep the Ministry informed of the operation and performance of the facility.

3. The reason for Condition No. 3 is to ensure that all samples are analyzed by methods acceptable to the Ministry.

4. The reason for Condition No. 4 is to ensure that all sampling and analytical results conducted at the facility will be submitted to the Ministry.

5. The reason for Conditions No. 5 and No. 6 is to ensure that all monitoring and analytical equipment are properly maintained to ensure accuracy.

6. The reason for Condition No. 7 is to ensure that unintentional discharges to the environment that exceed the maximum allowable concentrations are reported to the Ministry in order to determine if further action is required.

You may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board.

This Notice should be served upon:

The Secretary,
Environmental Appeal Board,
1 St. Clair Ave. West,
5th Floor,
Toronto, Ontario.
M4V 1K7

AND

The Director,
Section 24, O.W.R. Act
Ministry of the Environment,
135 St. Clair Ave. West,
Toronto, Ontario.
M4V 1P5.

DATED at Toronto this 4th day of November, 19 86.

Environmental
Appeal Board

1 St. Clair Avenue West
Toronto, Ontario
M4V 1K7

FORM OF NOTICE OF APPEAL

EXPLANATORY NOTES

Appeals to the Environmental Appeal Board should be made in the attached form, which is intended to provide the Board and the respondent with specific details regarding the nature of the appeal.

The form has been structured to allow sufficient space for a typical appeal, and two copies of the form are attached in case the appellant wishes to insert the information on the form provided. A third copy is attached for retention by the appellant.

The form is not intended to be restricting or confining and if, in a particular case, it is found that insufficient space is available on the forms provided, the particulars may be attached on additional plain white sheets.

In some cases, appellants may prefer not to use the forms provided by the Board. The Board will accept Notices of Appeal submitted on the appellant's stationery, provided that the required format and particulars as indicated on the Board's form are present.

APPENDIX B

WATER TREATMENT CHEMISTRY ANALYSIS

DELTA WATER TREATMENT CHEMISTRY RESULTS / B (CHANNELS) FIELD

Sample Date	Location	Analyst	Benzene PPB	Toluene PPB	Ethylben PPB	Xylene PPB	T Phenol PPB	Fe PPM	Napthal. PPB	Trimetben PPB	% Recovery or D10 Anthracene
1-22-87	B - Tap	Mann Labs	150.2	31.3	92.1	102.6	NA	NA	30.6	106.4	
2-04-87	B - Tap	J. Poland	135.0	20.0	149.0	231.0	NA	NA			
2-26-87	B - Tap	J. Poland	116.0	8.1	102.0	125.0	1.0	0.90			
4-21-87	B - Tap	J. Poland	103.0	12.3	98.0	121.0	5.4	1.90			
4-30-87	B - Tap	J. Poland	89.0	7.9	86.0	94.0	3.8	1.78			
5-13-87	B - Tap	Mann/Poland	80.3	1.4	116.3	51.6	4.3	0.15	7	49.8	90%
5-19-87	B - Tap	J. Poland	75.0	1.4	63.0	41.0	3.9	1.27			
6-03-87	B - Tap	J. Poland	82.0	<1.0	49.0	19.1	10.4	2.55			
6-15-87	B - Tap	P/BC/M	74.0	1.1	56.0	29.0	<2.0	0.26	4		103%
7-10-87	B - Tap	Bon-Clegg	NA	NA	NA	NA	3.0	0.58			
7-28-87	B - Tap	J. Poland	55.0	<1.0	34.0	11.9	5.1	NA			
8-05-87	B - Tap	J. Poland	60.0	<1.0	37.0	10.8	5.2	1.20			
8-11-87	B - Tap	J. Poland	55.0	<1.0	32.0	7.8	10.2	1.14			
9-03-87	B - Tap	J. Poland	64.0	<1.0	11.5	1.9	4.2	1.88			
9-23-87	B - Tap	J. Poland	53.0	<1.0	35.0	<5.0	11.5	1.52			
10-13-87	B - Tap	J. Poland	47.0	<1.0	<5.0	32.0	NA	1.43			
11-18-87	B - Tap	J. Poland	38.0	<1.0	25.0	<5.0	2.0	1.57			
1-05-88	B - Tap	J. Poland	33.0	<1.0	<2.0	23.0	<1.0	1.34			
2-02-88	B - Tap	J. Poland	26.0	<1.0	<2.0	27.0	4.0	1.44			
4-30-87	Mid B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-19-87	Mid B Channel	J. Poland	9.1	<1.0	<1.0	1.3	<1.0	<0.10			
7-10-87	Mid B Channel	Bon-Clegg	NA	NA	NA	NA	<2.0	0.06			
8-05-87	Mid B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	2.3	0.14			
8-11-87	Mid B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
6-15-87	Mid C Channel	Poland/BC	<1.0	<1.0	<1.0	<1.0	<2.0	<0.05			
6-24-87	Mid C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	5.2	<0.10			
7-10-87	Mid C Channel	Bon-Clegg	NA	NA	NA	NA	<2.0	<0.05			
8-05-87	Mid C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	0.48			
8-11-87	Mid C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-13-87	End A Channel	Mann/Poland	-	-	TR	TR	<1.0	<0.10	-	-	77%
5-19-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-27-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
6-15-87	End A Channel	Poland/BC	<1.0	<1.0	<1.0	<1.0	<2.0	0.13			
6-24-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
7-10-87	End A Channel	Bon-Clegg	NA	NA	NA	NA	<2.0	<0.05			
7-28-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	1.8	NA			
8-05-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	0.16			
8-11-87	End A Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
1-22-87	End B Channel	Mann Labs	-	-	-	-	NA	NA	-	4.0	
1-27-87	End B Channel	J. Poland	5.1	<1.0	<1.0	2.6	<1.0	0.05			
2-04-87	End B Channel	J. Poland	3.5	<1.0	3.9	3.2	<1.0	0.28			
2-26-87	End B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	2.3	NA			
4-21-87	End B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	3.6	0.15			
4-30-87	End B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
7-28-87	End B Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0				
4-15-87	End C Channel	P/BC/M	1.2	<1.0	<1.0	<1.0	13.0	<0.05	TR		96%
5-13-87	End C Channel	Mann/Poland	-	-	-	TR	<1.0	<0.10	-	-	77%
5-19-87	End C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-27-87	End C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
6-15-87	End C Channel	Poland/BC	<1.0	<1.0	<1.0	<1.0	31.0	0.09			
6-24-87	End C Channel	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			

[illegible] TR = trace; - = none detected; NA = not analyzed; [illegible] = broken bottle;)

DELTA WATER TREATMENT CHEMISTRY RESULTS / A (GRASS) FIELD

Sample Date	Location	Analyst	Benzene PPB	Toluene PPB	Ethylben PPB	Xylene PPB	T Phenol PPB	Fe PPM	Napthal. PPB	Trimetben PPB	% Recovery or D10 Anthracene
4-15-87	A - Tap	P/BC/M	133.0	5.3	115.0	79.0	59.0	1.20	4		69%
5-06-87	A - Tap	J. Poland	84.0	2.8	79.0	66.0	5.4	2.00			
5-27-87	A - Tap	J. Poland	74.0	<1.0	54.0	36.0	4.4	1.44			
6-03-87	A - Tap	J. Poland	81.0	<1.0	49.0	19.0	10.2	2.53			
6-24-87	A - Tap	J. Poland	70.0	1.6	46.0	24.5	2.1	1.25			
4-15-87	End Grass Field	P/BC/M	<1.0	<1.0	<1.0	<1.0	<2.0	<0.05	TR		90%
4-21-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	3.8	<0.10			
4-30-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-06-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-13-87	End Grass Field	Mann/Poland	-	-	-	-	<1.0	<0.10	-	-	110%
5-19-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-27-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
6-15-87	End Grass Field	Poland/BC	<1.0	<1.0	<1.0	<1.0	<2.0	<0.05			
6-24-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
7-10-87	End Grass Field	Bon-Clegg	NA	NA	NA	NA	<2.0	0.06			
7-28-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	NA			
8-05-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
8-11-87	End Grass Field	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			

NOTES: < = less than; TR = trace; - = none detected; NA = not analyzed; X = broken bottle;]

DELTA WATER TREATMENT CHEMISTRY RESULTS / CEMENT EXIT NOTCH TO FOUNDARY CREEK

Sample Date	Location	Analyst	Benzene PPB	Toluene PPB	Ethylben PPB	Xylene PPB	T Phenol PPB	Fe PPM	Napthal. PPB	Trimetben PPB	% Recovery or D10 Anthracene
4-15-87	Cement Notch	P/BC/M	<1.0	<1.0	<1.0	<1.0	10.0	<0.05	TR		74%
4-21-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	2.9	<0.10			
4-30-87	Cement Notch	J. Poland	X	X	X	X	<1.0	<0.10			
5-06-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	0.20			
5-13-87	Cement Notch	Mann/Poland	-	-	-	-	X	<0.10	-	-	74%
5-19-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
5-27-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
6-15-87	Cement Notch	P/BC/M	<1.0	<1.0	<1.0	<1.0	<2.0	<0.05	-		100%
6-24-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
7-10-87	Cement Notch	Bon-Clegg	NA	NA	NA	NA	<2.0	<0.05			
7-28-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	NA			
8-05-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
8-11-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
9-02-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
9-23-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
10-13-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	NA	<0.10			
11-18-87	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
1-05-88	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10			
2-02-88	Cement Notch	J. Poland	<1.0	<1.0	<1.0	<1.0	<1.0	0.36			

NOTES: < = less than; TR = trace; - = none detected; NA = not analyzed; X = broken bottle;]

APPENDIX C

BENZENE IN HOME WELLS

Delta Home Sampling - BENZENE (PPB)

Lot	Name	System	12-4-87	7-20-87		6-15-87		4-15-87	1-14-87		8-11-86	4-02-86		2-06-86		1- -86		11-11-85		9- -85		7-22-85		5- -85	
			unfilt	unfilt	filt	unfilt	filt	unfilt	unfilt	filt	unfilt	unfilt	filt	unfilt	filt	unfilt	filt	unfilt	filt	unfilt	filt	unfilt	filt	unfilt	filt
12																						0.2			
13	Steary			0																		<0.1		<0.5	
14	Vollick			0	0	<1.0																<0.1		<0.5	
15	Pratt B.		<1.0																						
16				0		<1.0																0.5			
17	Pratt I.	ACF-P		0	0	<1.0		<1.0		<1.0	47.1									21.0	1.7	153.0		131.0	0.8
18	Halliday	ACF-P		3	0	1.7			31.9		42.6											86.0	0.7		
19	Jacques	ACF-P-WD		0	0	2.8		<1.0	16.0		<1.0			207.0	1.9							<0.1	0.4	<0.5	<0.5
20	Donald	ACF-S-WD		0		26.3		2.8	130.0		<1.0	740.0		926.0	10.3	836.0	10.0	524.0	21.0	404.0	2.1	898.0	220.0		
21	Price	ACF-P-WD			0	<1.0		142.0			2.5											8.9		<0.5	<0.5
22	Grant			0																0.6		1.6			
24	Ayres			0		<1.0						<0.5								<0.2		1.0			
25	Phillips	ACF-WD		0	0	<1.0						121.0								6.6	0.2	9.0	9.6		
26	Connell	WD				<1.0		7.5				785.0						74.0				84.0			
27	Pratt Apts	ACF		6		4.2		3.6	27.0		5.0									0.7		22.0		7.5	
28	Gray G.			0							<1.0											0.6		<0.5	
29	French		<1.0	0		<1.0		<1.0												1.6		3.2		<0.5	
30	Coon	ACF		0	0	<1.0			<1.0		<1.0	<0.5						1.0		1.2		26.0			
31	Sly	Mon		0	0	<1.0														6.1		6.8		<0.5	
32	Breedyk	Mon		0		<1.0		<1.0	<1.0		2.1	4.6		6.4				8.0		5.7		3.1			
43	SCHOOL WR	ACF-3		0			<1.0			<1.0															
43	SCHOOL BR	ACF-3				<1.0			<1.0		<1.0							2.0		1.6	2.1	7.8		0.8	
45	Laforty	ACF		0	0	<1.0		18.4	<1.0			85.0	<0.5	146.0		126.0		158.0		92.0	1.9	428.0	<0.1	-	-
46	Atkin										57.5											<0.1			
47	Gray K.	ACF				<1.0		<1.0	1.4		<1.0	3.4										21.8			
48	Henderson	ACF		0	0	<1.0																			
49	Kitson			0	0	<1.0								<1.0		<1.0		<1.0				<0.1		<0.5	
50	Wing	ACF	<1.0	0		<1.0			<1.0		<1.0	<0.5						<1.0				17.5			
51	POST OFFICE	WD		0		<1.0																<0.1			
52	Halliday E.			0		<1.0		<1.0	<1.0		<1.0	<0.5		<1.0		<1.0						<0.1			
53	U.CHURCH			0																		0.4			
54	Stankiewi			0																		<0.1			
55	Russell H.			0																					
56	U.M.P.			0																1.4		1.0		<0.5	
57	Gravelle			0																					
60				0																					
99						<1.0																			
172	Russell L.			0																					
173	Schleede			0																		<0.1			
174	RED & WHITE			0		<1.0		<1.0				<0.5						<1.0		1.0		1.7			
175	LIQUOR STORE			0		<1.0																<0.1			

NOTES:

System Delivery: ACF-P = Activated Carbon Filter - Parallel
System Delivery: ACF-P-WD = Activated Carbon Filter - Parallel - Water Delivery
System Delivery: ACF-S-WD = Activated Carbon Filter - Series - Water Delivery
System Delivery: Mon = Monitor

Sampling on 7-20-87 done in conjunction with MOE
Sampling on 12-4-87 were newly completed wells

APPENDIX D

PIEZOMETER WATER LEVELS

CALCULATION OF POTENTIOMETRIC ELEVATIONS

Bedrock Piezometers

					April 2, 1986			January 8, 1987			May 27, 1987			June 15, 1987			August 5, 1987		
LOCATION	DEPTH Piezometer (m)	HEIGHT Piezometer (m)	ELEVATION Ground (m)	ELEVATION Ground (m)	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES
D1-Well		0.39		93.39				0.03	93.42				2	0.02	93.41		-0.65	92.74	
D1-1	30.5	0.32	62.89	93.39	-6.23	87.16				7			2	0.32	93.71	7	-7.09	86.30	
D1-2	21.3	0.32	72.09	93.39	0.04	93.43	6			7			2	0.32	93.71	7	-0.73	92.66	
D1-3	~12.2	0.32	81.19	93.39	0.01	93.40	6			7			2	0.32	93.71	7	-0.20	93.19	
D2-Well		0.73		96.93				0.73	97.66				2	0.73	97.66		0.73	97.66	
D2-1	30.5	0.80	66.43	96.93	-2.68	94.25		-2.02	94.92				2	-5.96	90.98		-4.68	92.26	
D2-2	26.8	0.79	70.13	96.93	-2.60	94.33		-1.84	95.10				2	-3.94	93.00		-5.07	91.86	
D2-3	21.3	0.77	75.63	96.93	-2.59	94.34		-1.79	95.15				2	-3.97	92.97		-5.15	91.79	
D2-4	9.1	0.79	87.83	96.93	-2.65	94.28		-2.10	94.83				2	-3.25	93.68		-3.48	93.46	
D2-5	~4.6	0.73	92.33	96.93	-2.47	94.46		-2.39	94.55				2	-3.16	93.78	9	-1.78	95.15	
D3-Well		0.66		95.31				-0.84	94.47				2	-1.05	94.26		-2.25	93.06	
D3-1	30.5	0.26	64.81	95.31	-1.29	94.02		-1.48	93.84				2	-3.98	91.33		-2.34	92.97	
D3-2	24.4	0.26	70.91	95.31	-1.28	94.03		-1.48	93.83				2	-1.89	93.42		-2.37	92.95	
D3-3	16.8	0.26	78.51	95.31	-1.15	94.16		-1.32	93.99				2	-1.83	93.48		-2.47	92.84	
D3-4	9.1	0.26	86.21	95.31	-1.01	94.30		-1.20	94.11				2	-1.43	93.88		-2.47	92.84	
D4-Well		0.68		94.80				-0.49	94.31				2	-0.65	94.15		-0.77	94.03	
D4-1	45.7	0.07	49.1	94.80	-3.04	91.76		-1.28	93.52				2	-4.15	90.65		-3.38	91.42	
D4-2	42.1	0.07	52.7	94.80	-0.81	93.99		-1.27	93.53				2	-1.51	93.29		-1.90	92.90	
D4-3	25.0	0.07	69.8	94.80	-0.78	94.02		-1.20	93.60				2	-1.53	93.27		-1.96	92.84	
D4-4	8.5	0.07	86.3	94.80	-0.75	94.05		-1.23	93.57				2	-1.85	92.95		-1.91	92.89	
D5-Well		0.44		93.56				0.44	94.00				2	-0.14	93.42		-1.17	92.39	
D5-1	30.5	0.01	63.06	93.56	-1.17	92.39				6			2	-2.99	90.57		-3.59	89.97	
D5-2	22.9	0.01	70.66	93.56	0.39	93.95	6			6			2	-2.89	90.67		-2.60	90.96	
D5-3	18.3	0.01	75.26	93.56	0.66	94.22				6			2	-0.63	92.93		-1.42	92.14	
D5-4	13.7	-0.03	79.86	93.56			6			6			2	-0.63	92.93		-1.43	92.13	
D6-Well		0.35		93.39				-1.10	92.29				2	-1.24	92.15		-1.77	91.62	
D6-1	30.5	0.33	62.89	93.39	-1.22	92.17		-1.21	92.19				2	-1.37	92.03		-1.73	91.67	
D6-2	25.9	0.33	67.49	93.39	-1.22	92.17		-1.18	92.22				2	-1.34	92.06		-1.71	91.68	
D6-3	19.8	0.33	73.59	93.39	-1.19	92.20		-1.13	92.27				2	-8.48	84.92		-1.69	91.70	
D6-4	9.1	0.33	84.29	93.39	-1.21	92.18		-1.17	92.23				2	-1.47	91.93	?	-1.71	91.68	
D7-Well	54.25	0.42		95.95	-1.65	94.30		-1.04	94.91				2	-4.03	91.92		-5.52	90.43	

NOTES
1 - Not Located
2 - Not Recorded
3 - Destroyed
4 - Ice in Piezometer
5 - Frozen, No Levels
6 - Artesian Flow
7 - Submerged Below Water
8 - Dry?
9 - Obstruction
? - Questionable Level

CALCULATION OF POTENTIOMETRIC ELEVATIONS

Overburden Piezometers

LOCATION	DEPTH Piezometer (m)	HEIGHT Piezometer (m)	ELEVATION Ground (m)	ELEVATION Ground (m)	April 2, 1986			January 8, 1987			May 27, 1987			June 15, 1987			August 5, 1987		
					measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES	measured water level (m)	Piezometric Surface (m)	NOTES
GD1-1	7.62	0.00	89.85	97.47	-2.89	94.58				1			1			1			1
GD1-2	6.71	0.00	90.76	97.47	-2.89	94.58				1			1			1			1
GD1-3	4.88	0.00	92.59	97.47	-2.89	94.58				1			1			1			1
GD1-4	3.05	0.00	94.42	97.47			8			1			1			1			1
GD2-PVC	12.09	-0.10	84.47	96.56	-1.98	94.58				1			2	-11.60	84.96	?	-4.02	92.54	
GD2-2	10.59	-0.15	85.97	96.56	-1.99	94.57				1			2	-9.97	86.59	?	-2.46	94.10	
GD2-3	9.09	-0.13	87.47	96.56	-2.00	94.56				1			2	-3.05	93.51		-4.06	92.50	
GD2-4	7.59	-0.10	88.97	96.56	-2.00	94.56				1			2	-3.70	92.86	9	-1.85	94.71	
GD2-5	6.09	-0.10	90.47	96.56	-2.00	94.56				1			2	-5.50	91.06	8	-3.21	93.36	
GD3-PVC	12.02	-0.03	84.32	96.34	-1.73	94.61				1			2			2	-3.79	92.55	
GD3-2	10.52	-0.04	85.82	96.34	-1.74	94.60				1			2			2	-3.79	92.55	
GD3-3	9.02	-0.04	87.32	96.34	-1.73	94.61				1			2			2	-3.80	92.54	
GD3-4	7.52	-0.04	88.82	96.34	-1.73	94.61				1			2			2	-3.81	92.54	
GD3-5	6.02	-0.04	90.32	96.34	-1.74	94.60				1			2			2	-3.82	92.52	
GD4-PVC	11.42	0.70	83.84	95.26	-0.92	94.34		0.30	95.57	4	-7.80	87.46		-7.97	87.29	8	-3.61	91.65	
GD4-2	10.42	0.70	84.84	95.26	-0.81	94.45		0.14	95.40	4	-3.35	91.91		-8.05	87.21	8	-3.43	91.83	
GD5-PVC	12.48	0.42	83.13	95.61	-1.09	94.52		0.10	95.71	4	3.23	92.38		-1.96	93.65				
GD5-2	11.48	0.41	84.13	95.61	-1.08	94.53		0.08	95.69	4	-6.65	88.97	8	-11.60	84.02	8	-3.04	92.57	
GD5-3	10.48	0.41	85.13	95.61	-1.08	94.53		0.05	95.66	4	-3.29	92.32		-6.39	89.22	8	-3.31	92.30	
GD5-4	9.48	0.42	86.13	95.61	-1.02	94.59		0.25	95.86	4	-3.29	92.33		-1.82	93.80		-3.30	92.32	
GD5-5	8.48	0.44	87.13	95.61	-0.96	94.65		0.03	95.65	4	-9.59	86.03	8	-1.91	93.71		-3.17	92.44	
GD5-6	7.48	0.46	88.13	95.61	-1.08	94.53		0.03	95.64	4	-3.19	92.42		-1.94	93.67		-3.20	92.41	
GD5-7	6.48	0.41	89.13	95.61	-1.11	94.50		0.11	95.72	4	-4.25	91.37	?	-2.29	93.33		-3.33	92.28	
GD6-PVC	9.09	0.60	85.73	94.82	-0.31	94.51		0.51	95.33	4	-2.45	92.37		-1.10	93.72		-2.56	92.26	
GD6-2	8.09	0.60	86.73	94.82	-0.30	94.52		0.22	95.04	4	-2.45	92.37		-7.30	87.52		-2.56	92.26	
GD7-PVC	8.86	0.27	86.15	95.01	-0.82	94.19		0.24	95.25	4			2			2	-2.56	92.46	8
GD7-2	7.87	0.27	87.14	95.01	-2.15	92.86		0.05	95.06	4			2			2	-1.11	93.90	
GD8-1	4.50	-	91.06	95.56	-1.64	93.92				3			3			3			3
GD9-PVC	5.03	0.92	91.31	96.34			8	-1.58	94.76	4	-3.48	92.86	?	-4.71	91.63	8	-3.44	92.90	?
GD10-PVC	16.38	0.73	79.45	95.83	-1.67	94.16		-1.93	93.90		-16.27	79.56	8	-3.17	92.66		-3.50	92.33	
GD10-2	15.38	0.71	80.45	95.83	-1.66	94.17				5	-4.29	91.54	?	-3.64	92.19	?	-3.55	92.28	
GD10-3	14.38	0.71	81.45	95.83	-1.67	94.16				5	-4.29	91.54	?	-3.69	92.14	?	-3.55	92.28	
GD10-4	13.38	0.71	82.45	95.83	-1.68	94.15		-1.62	94.21		-4.29	91.54	?	-3.40	92.43		-3.54	92.29	
GD10-5	12.38	0.71	83.45	95.83	-1.68	94.15		-1.74	94.09				2	-3.93	91.90		-3.55	92.28	
GD10-6	11.38	0.71	84.45	95.83	-1.68	94.15		-1.82	94.01		-11.29	84.54	8	-3.39	92.44	?	-3.53	92.30	
GD10-7	10.38	0.71	85.45	95.83	-1.68	94.15		-1.69	94.14				2	-3.74	92.09	?	-3.53	92.30	

TD
426
.L68
1989

Low cost treatment technology
for gasoline contaminated
groundwater-delta, Ontario /
Woeller, R. M.

77116